GENERAL SCIENCE

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WITH

Experimental and Project Studies

BY

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WITH 334 ILLUSTRATIONS

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PREFACE

The purpose of this book is to supply opportunities for actual contact with the materials and forces in nature that have real significance in the life of boys and girls. In order to do this the method of the book is to take up first in each of its chapters the study of several exercises before plunging into the main theme of the chapter. The purpose of each and every exercise is to bring about a natural development of interest, appreciation, and power. The fundamental truths, which are discovered while working out the preliminary exercises, are not only duly emphasized at the time, but are extended to larger points of view. Each chapter closes with a series of suggested projects. These projects are proposed as self activities, and it is this portion of the course that is the most interesting, most practical, and most calculated to call forth genuine thought and concentrated effort on the part of the student. It is not intended that a pupil shall confine his selection of a project to those suggested, for others of greater interest and of more vital importance will often arise. However, in no case should a pupil undertake a project which the teacher of the course knows to be beyond the ability of the boy or girl making such a choice.

The theme throughout this book is LIFE and deals with man in particular. To accomplish the purpose of the theme the book is divided into three lesser themes, which grow out of each other in natural sequence,—

I. Man's adjustment of nature's forces and materials to the comforts of life.

II. Conditions necessary for life and growth.

III. Improving the conditions of human life and growth.

Each of the above sections is divided into large units which are closely related to the main theme. The early units are simple and easy of mastery. However, as the course proceeds the degree of complexity gradually increases step by step in

order that the conclusion of the course may be attained with a corresponding mental growth and development on the part of the pupil.

Acknowledgment for much help and contributions of materials and data is due to the Department of Agriculture; Department of Interior; Chambers of Commerce located in New York City, Chicago, Cleveland, St. Louis, and Portland, Oregon; and to the publishers, Messrs. P. Blakiston's Son & Co., for the loan of many figures from the works of Tower, Smith, Turton, and Cope, of Galloway, and of others.

The author wishes to express his appreciation to many friends, fellow teachers, and especially to the students of the general science classes of the past few years who have contributed much toward the preparation of the book; to W. C. Devereaux of the Abbe Meteorological Observatory, Cincinnati; to Genevieve Dennison, Head of the English Department, University School, Cincinnati, who has read the proof and contributed many valuable suggestions; and to Lucy Bell Bowden for her untiring efforts and able assistance in making this book what it is.

G. A. B.

Cincinnati, Ohio.

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GENERAL SCIENCE

SECTION I

MAN'S ADJUSTMENT OF NATURE'S FORCES AND MATERIALS TO THE COMFORTS OF LIFE

Primitive Progress.—From the very earliest times the story of man's progress relates his struggle for mastery of the forces and uses of the materials that he found in the world around him. The progress from the first was slow, and, indeed, many centuries passed before he became skilled in shaping weapons for defense and hunting, in perfecting the art of boat building, and in developing means for preparing and weaving plant fibers into clothing materials. This heavy toil was performed at the expense of human energy.

Putting the Forces of Nature to Work.—In some manner man discovered that the wind would drive his boat, and thereupon he invented a sail and set it to a mast. He soon learned how to tack the boat and thus to travel far with less expenditure of his bodily energy. The wind that heretofore opposed him was now harnessed to his boat. The captured ox became a beast of burden in a more or less limited way. But with the invention of the wheel, the plow, and the yoke, the ox was put to new labors of drawing loads and turning over the soil of larger fields. The water-fall opposed man when he journeyed up and down the water routes. The invention of a water wheel harnessed the force of the water-fall to his mill and thus ground his grains. The story of the advancement of man may be told in the narration of his creation of harnesses for the various forces that he met in nature. He desired for decades to harness heat, and this was finally accomplished with the invention of a steam engine.

After the First Steps Advancement was Rapid.—Each new force brought to the service of man stimulated progress in every art. New and better materials were speedily brought into use. Improved and more efficient tools and machinery

were designed and constructed. As each new tool or instrument became more and more efficient, man pried deeper into nature's store house of energy and materials, until today his wants are few that he can not satisfy.

Loss of Independence.—Along with this development have come many sacrifices. At the beginning every man hunted his own game, made his own bows and spears, and fashioned his own clothes from leather that he himself had tanned and prepared. He was independent of every other man. Today it is greatly different. In some manner each man is dependent upon every other man. So deeply is society organized that the failure of one individual or group of individuals produces losses that disturb us all. While seated at the breakfast table think of the thousands of laborers who in one way or another had a hand in gathering together the raw materials and in manufacturing the various articles and foods displayed before you. Are you able to make the analysis complete? Is there any one article on the table which you could prepare from its raw materials to the finished product?

Preparation is Necessary.—To take part in such an organized world one should seek to know about it in order that he may appreciate the many services that the great multitude of humanity renders to him. A course in general science is a step in this direction. Its purpose is simply to point the way into the "how and why" of things that surround us on every hand. This done, we shall be better able to take the more advanced steps that await us as we pass on to the affairs of the greater spheres of life.

UNIT I

HEAT, ITS PRODUCTION AND APPLICATION TO THE NEED OF MAN

CHAPTER I

THE ART OF MAKING FIRE

Object.—1. To make a study of the various methods that man has used to produce heat with which to kindle his fire.

2. To make a study of the principles underlying the construction of the match and to formulate a set of "safety first" rules regarding its use.

A Spirit of Inquiry Precedes Scientific Achievement.—Many of us have become so accustomed to the use of matches for the purpose of starting fires that we do not stop to think that this method of starting fires was not in use one hundred years ago. In order to appreciate a scientific achievement it is often necessary to inquire into the methods or means employed before the present-day method came into use. Another way to bring out the importance of a present-day method of doing things is to inquire of one's self the possibility of finding other means of accomplishing the end desired. This is exactly what the inventor does; he seeks to find a simpler and more serviceable method than the one in use. In order to show the importance of matches some historical methods for making fire are suggested. Some of the suggested methods were used by ancient man and are still used by savage peoples who occupy the few remaining and not easily accessible corners of the earth.

METHODS INVOLVING FRICTION

1. Briskly rub a penny on your clothing or other flat surface and then quickly place the coin on the palm of your hand. What is the sensation? Using more pressure repeat the experiment. Result? Does an increase in pressure cause greater friction between the rubbing surfaces? What

relation does an increase or decrease of the amount of friction between the rubbing surfaces bear to the heating effects?

2. Obtain two pieces of soft wood and rub them vigorously against each other. Feel the surfaces with the palm of your hand. The effects are slight even when you use a great deal of pressure.

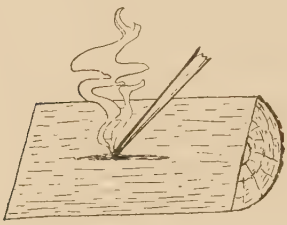


FIG. 1.—Stick and groove machine.

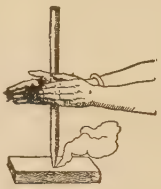


FIG. 2.—Fire boring machine.

3. Place a piece of lead or copper upon an anvil or an old flat iron and pound it with a hammer. Immediately transfer the hammered copper or lead article to the palm of your hand. Result?

4. Stick and groove machine. On the surface of a piece of board make a groove with some dull instrument. In the groove thus made place the point of a hardwood stick and rub forth and back with a rapid motion. Is there any effect? Do you think that you could cause the board to take fire by rubbing continuously in this manner for some minutes? Did savage people ever use this method? Historians call this the "stick and groove" machine.

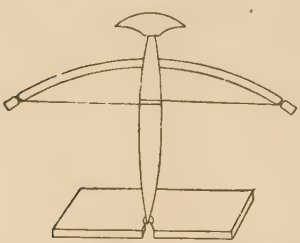


FIG. 3.—Boy Scout apparatus. (*From Tower, Smith, Turton, and Cope's Physics.*)

5. Fire borer. Make a depression in a piece of soft wood and place in this depression the pointed end of a round stick. Roll the stick forth and back between your hands. Are you able to cause a smoldering of the wood to take place? Did ancient man depend upon this method for producing fire? Do the present-day savages, who live in remote places, use this method for making fire?

6. Boy Scout apparatus. Rig up a boy scout fire-making apparatus according to directions given in the boy scout manual and endeavor to kindle a fire. Which of the above methods do you consider the best for kindling fires? Are these methods dependable? Explain your answer. Do they require a great deal of energy, skill, and patience? What peoples of the present day depend upon these, or very similar methods, for kindling their fires? Why is this method of producing fire required of boy scouts?

7. Obtain two pieces of flint. Strike the edge of one with a glancing blow against the edge of the other. Did you succeed in driving off into

the air a series of sparks? If not, repeat the operation and see if you are able to direct the sparks to a given place on the table.

8. Flint, steel, and tinder box. With a piece of flint strike a glancing blow against a piece of steel, or, better, a file. Is this method better than that of striking two flints? Obtain a suitable tin box with a well-fitted cover. Place two or three layers of linen or cotton cloth in the box. Place on a suitable support and heat it strongly for ten or fifteen minutes. Allow the box and contents to cool. When the box has thoroughly cooled carefully remove the cover. Now take the flint and steel and endeavor to direct a series of sparks into the charred remains of the cloth. When was this the common method for starting fires? Is this method convenient? Do you consider it more or less difficult than any of the methods suggested above?

THE BURNING GLASS

Secure a large lens or reading glass and with it concentrate the sun's rays upon some tufted cotton, a mass of fine shavings, or paper. Describe the effects. In this experiment what was the source of the heat? Did people ever use burning glasses, such as you have used here, for kindling their fires? Could they make use of the burning glass at all hours of the day and every day? Explain.

THE MATCH

Obtain some common matches and a box of safety matches. Examine them thoroughly. Light one of each kind. Why is one called a "strike-anywhere" match and the other a "strike-on-the-box" match? Strike two or three of the common matches. Does the blazing head fly off, or the stick break easily while striking the match? Does the match continue to glow after the flame has been blown out? These are signs which tell whether the match is poorly or properly made. Cheap brands use cheap materials. Good matches do not break, do not allow the blazing head to fly off, and do not glow after the flame has been blown out. Apply the same test to several of the safety or "strike-on-the-box" matches. Do you find them to be safe or dangerous? Explain. Examine the head of a "strike-anywhere" match. Do you find a black bulb surrounding the white head? The black substance is placed there to prevent the head from flying off when struck, and also to guard it from being set on fire accidentally. Examine the labels on the boxes. Do you find "The National Board of Fire Underwriters" label on the boxes? Such labels are considered a protection against poor brands of matches, for any manufacturer who will make the right grade of goods can secure the right to use the label.

The Art of Making Fire.—The story of the human race may be divided into two great periods, the prehistoric and the

historic. During the prehistoric period primitive man learned many hard lessons in his battle for the bare necessities of a livelihood. During this period he discovered fire and learned to use it as a means of warming his body, cooking his foods, and protecting himself against preying animals. Nobody can tell how or when fire was first discovered. The story told by Lucretius describes the rubbing together of dry tree branches as the origin of fire, but this is very doubtful and very likely not to have been the case. Forests are often set afire by light-

FIG. 4.—Primitive man still roams the Amazon Jungle. Just how primitive the Carajos Indian is may be judged by his method of getting fire by rubbing sticks together. This method antedates flint and steel, and the tinder box, by many thousands of years. (*Copyrighted by The Keystone View Co. Inc. of N. Y.*)

ning and by erupting volcanoes, and from this possible origin it is likely that ancient man made his first acquaintance with fire and its uses. Again, the savage in every age has made use of pieces of flint with sharp edges for cutting and sharp points for arrows and spears. He learned to improve the form of these stone implements by striking or chipping and grinding off unnecessary portions. During these processes it is quite certain that heat was developed and sparks were produced, and such sparks may have been the origin of the cave man's fire.

The Fire Boring Machines.—The Carajos Indians, who, today, live in the wilds of the upper Amazon, make use of a round pointed stick, which they rapidly roll forth and back between the palms of the hands while pressing the pointed end against a suitable piece of timber wood. Until quite recently the same method was used by the natives of Australia and Tasmania. The savage became skilled in the application of these methods. Darwin, who visited the savages at Tahiti, writes that they seldom failed in the first attempt to kindle a fire. In the case of the Esquimaux, one presses the end of a spindle-shaped stick against a piece of wood, while a second produces a to-and-fro rotation by means of a thong which may or may not be fastened in a bow. This method is quite similar to the boy scout method for making fire. According to the historian Tylor the fire-borer is among the oldest of inventions.

Effects of the Discovery of Fire.—Prehistoric man gradually learned or accidentally discovered many uses for his fire. He found that it would harden clay, and he became a potter and developed the art of pottery. When he found that it liberated the metals from their ores, he built a forge and became a worker of metals, and thus the progress of man was quickened. Indeed, it is difficult to conceive how, without fire, primitive man could ever have emerged from the savage state, for it made possible the camp fire around which groups of savage men loved to assemble. These groups about the camp fire brought about the family and tribal unions from which our present-day society of human beings has developed with its multitude of complex and intricate problems.

The Tinder Box; Flint and Steel.—The ancient methods for the production of fire were laborious and uncertain, and it was always the hope of man that better methods might come into use. The flint and steel accompanied by a tinder box were long employed. To make the tinder several layers of pure linen were cut to fit the bottom of the tinder box, which, with its cover securely fastened, was placed on some coals of fire in the fire place. The heating of the closed tinder box resulted only in charring the linen. Charred linen is a very

combustible substance requiring only a small spark from the steel and flint to ignite it. The tinder box method for starting fires was regarded as a great convenience. In fact the children of colonial times found this method easy of application. The flint and steel combination for producing sparks was employed on the first fire arms. Such fire arms were used in our Revolutionary War, and were still in common use in some frontier places during the first half of the last century.

Matches.—Friction matches were introduced early in the nineteenth century and about the year 1834 came into practical use. The first brought out were known as the sulphur or Lucifer matches. They consisted of splinters of wood partly coated with sulphur bearing on the tip a mixture of gum, potassium chlorate, and antimony trisulphide. When these matches were drawn over a rough surface, enough heat was developed to ignite the mixture on the end, which lighted the sulphur which in its turn kindled the wooden splinter. These matches gave off an offensive odor on account of the burning sulphur, and were slow and uncertain in their action, and for these reasons were replaced by the parlor match.

The parlor match consisted of wooden splints partly coated with paraffin and tipped with a mixture of potassium chlorate, yellow phosphorus, and glue. This match ignited more easily and more readily than the old sulphur match; indeed, it ignited so easily that it often caused accidental fires when handled roughly during transportation or carried in the pocket with other articles that rubbed against the tipping mixture. However the yellow phosphorus used in the manufacture of the parlor match presented a more serious trouble. During the manufacturing process the yellow phosphorus was absorbed into the systems of the workmen, giving rise to a terrible disease known as "phossy jaw." For this reason laws have been passed in many countries, such as Switzerland and recently in the United States, that forbid the manufacture and sale of this match.

The dangers that attended the manufacture and use of the parlor match led to the development of the so-called "safety match." This match carries no phosphorus in its tipping

mixture, which is made up of substances rich in oxygen, such as potassium chlorate or sodium chromate, with a combustible like antimony trisulphide, and some dextrin and filler of chalk. The side of the box, which is used as a striking surface, is painted with a mixture of red phosphorus, antimony trisulphide, and dextrin. The substitution of red phosphorus for the active and poisonous yellow kind, and the impossibility of any accidental ignition of such a match, make it ideal in many respects.

However the American people demand a "strike-anywhere" match, which is now being manufactured. This match is similar in all respects to the old parlor match, except that in its manufacture phosphorus trisulphide is used in place of the deadly yellow form. The best of the strike-anywhere matches have a black bulb surrounding the white or colored head. This black substance is placed there to prevent the head from flying off when struck, and also to guard it from being set on fire accidentally.

The Need of Conservation.—The National Board of Underwriters has estimated that more than seven hundred million matches are used each day in the United States. It is impossible for our minds to imagine the magnitude of this huge number of matches, and the gigantic amount of materials required to manufacture this one article so necessary in the requirements of our daily needs. Vast forest areas are annually exhausted in order to supply the wood for the sticks. The paper and match industries of this country have made and are making such demands upon our forests that we are today brought face to face with a serious national problem, that of conservation of our forests. The best method of conservation is to conserve the materials that are made of forest products, and thus it becomes the patriotic duty of every American to lessen the extravagant demands that he makes upon those industries that provide him with matches, paper, boxes, and like materials that are fast exhausting our forest resources.

To the Pupil.—At the close of the various sections of this text you will find a list of suggested projects. Select one of them. Look in libraries, museums, shops, factories, stores, in fact anywhere you may be able

to find information or materials needed in the development of your project. Develop your own outline, making it clear and brief. Then report to your instructor and class the result of your investigation. Have your drawings made beforehand on the black board or on large squares of paper. Make the drawings large enough to be seen easily from all parts of the class room. Make your explanation clear and simple in order that your classmates may understand you. If it is necessary to perform an experiment in order to demonstrate your project, you may find most of the apparatus in and about your home, in the various school departments of physics, chemistry, manual arts, and domestic science, and in the workshops in the school community.

Projects

1. To study the construction and operation of the flint lock gun used in Colonial days.

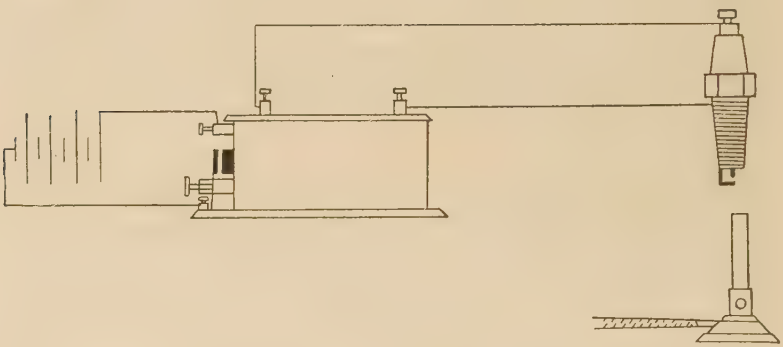


Fig. 5.

2. To study the construction and operation of a gas lighter. (See page 333, "Modern Chemistry and Its Wonders," by Martin.)

3. To study the effects of an electric spark on gas mixtures and to discover the commercial applications that are made of electric sparks to gas mixtures in gas engines by means of spark plugs. (See Fig. 5.)

4. To write three safety-first rules that will aid the purchaser to select the proper match, and to print these rules on a poster for display in the class rooms and halls of the school the week before fire prevention day.

5. To write five safety-first rules covering the use of matches and to print these on a poster for display purposes during a campaign for fire protection.

6. To make a study of match containers that are used in various homes, stores, factories, and public places, and to classify them as safe or dangerous.

7. To draw a set of poster cartoons that illustrate careless habits in the use of matches.

8. To write a short letter or theme that tells how to practice conservation in the daily use of matches.

9. To make the following calculations: If 700,000,000 matches are used daily in the United States.

(*a*) How many flames on the average are struck every second of a twenty-four hour day?

(*b*) How many days would it take a match factory running eight hours per day and making 1000 matches every second to supply our national needs for one day?

(*c*) How many factories, like that in (*b*), would be required to manufacture our daily needs? Our annual needs?

(*d*) If one match in every million is used so carelessly that it causes a destructive fire, how many such fires are possible each day throughout our country?

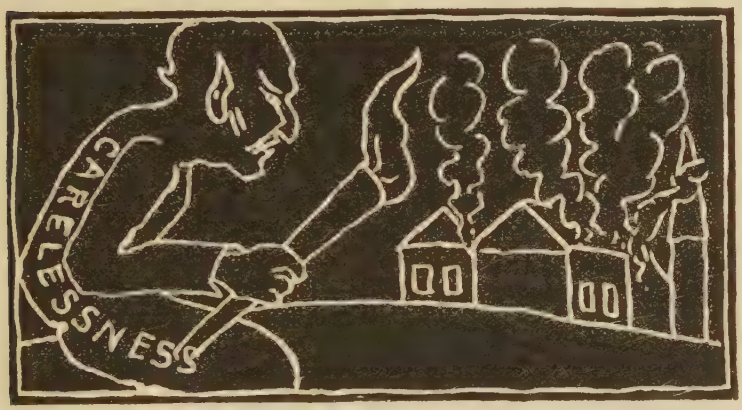


FIG. 6.

(*f*) If each fire in (*d*) represents a loss of $250, calculate our daily and annual losses. Do you think that we as a nation can stand such losses for any great length of time? Explain your answer.

CONSIDERATION.—Matches are one of the great conveniences of the age—a necessity to our welfare and happiness. It is not necessary that we go back to the ages of the tinder box and fire-boring machine. It is, however, necessary that every individual practice the highest type of citizenship and do all that is in his power to conserve the national resources of the nation and to make the best possible use of all the conveniences that society furnishes to him. Many of the conveniences that society provides are often misused by those who are thoughtless, ignorant, or disregardful of the consequences. The individual who is a true citizen makes use of the advantages and conveniences that society places about him, not alone for his own welfare but for the welfare of those about him and those who are to live in the generations that are to come.

CHAPTER II

WHY THE FIRE BURNS

Object.—1. To make a study of the conditions and factors that are favorable for a fire.

2. To make a study of the conditions and factors that are unfavorable for a fire and to apply these conditions and factors in order to know how to control or extinguish a fire.

Introduction.—After studying the methods for making a fire the next step is to endeavor to find out the best conditions under which the fire burns—that is, we want to know those conditions that are necessary and favorable for a fire. Most boys and girls know early in life how to make a bonfire. They know that leaves, paper, or bits of brushwood will burn, and that stones, dirt, sand, and water will not burn. Consequently when they want to make a fire they select those materials that will burn. Some know that air has something to do with the burning fuel, and so when a fire does not burn well they fan or blow it. Some may know that when the air is shut off the fire goes out. Our present study is, therefore, to examine those conditions that are favorable or unfavorable for a fire. A knowledge of both sets of conditions are necessary if we wish to understand *why the fire burns.* The following demonstrations and exercises will give us some helpful information that will aid us in searching for the answer to this question.

OXYGEN

Object.—To prepare oxygen and to study its relation to a burning substance.

APPARATUS.—Bunsen burner, iron ring stand, burette clamp, large test-tube provided with a one-hole stopper, one 6-inch and one 18-inch glass tube, two pieces of 4-inch rubber tubing, five wide mouth bottles and glass covers, and a pneumatic trough.

MATERIALS.—Matches, potassium chlorate, manganese dioxide, splinters of wood, a piece of charcoal, a piece of iron wire, a small piece of sulphur, 6 inches of picture wire, lime water.

PROCEDURE.—Fire polish each end of the glass tubes by holding the end of the tube in the flame of the Bunsen burner until the sharp edges are smooth and round, taking care not to soften the end too much and thus close the opening. Mix two parts of potassium chlorate with one part of manganese dioxide and then fill the test tube about one-half full with the mixture. Arrange the apparatus exactly as shown in figure, taking care to see that all the parts fit snugly together producing air tightness. Tap the test-tube gently so that the mixture lies in the manner shown in the figure. Have the instructor inspect your 'set up' before proceeding further.

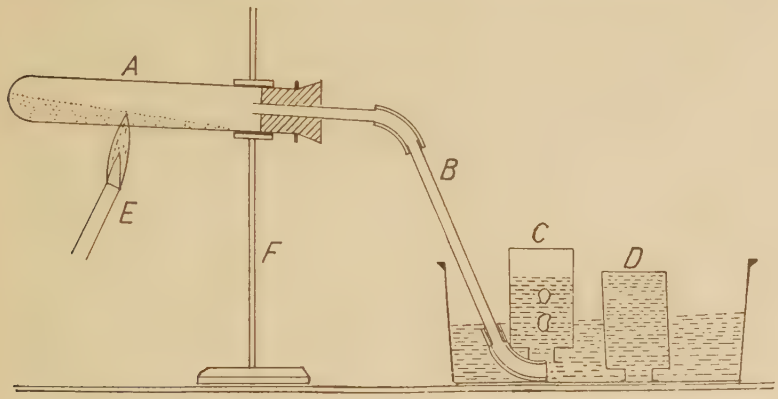


FIG. 7.—Apparatus for making oxygen.

Preparation of the oxygen. Apply the heat at first to the upper part of the mixture; proceed slowly, heating the mixture gently with a low flame and taking care not to set the cork on fire. A few bubbles of air will escape because of the expansion of the air within the tube, and then after a minute or so the oxygen will be set free. Regulate the heat so that the bubbles will come off in a slow procession; should they come off too rapidly, lessen the heat; if too slowly, increase it; if not at all, examine the stopper and all other connections for leaks and adjust accordingly. When the first bottle is full of gas remove the delivery tube and then the flame. Slip a glass cover under the bottle so as to close its mouth, and thus remove the bottle of gas and set it aside. Fill five bottles and immediately remove the delivery tube from the water lest the water be drawn up and into the hot test-tube as the hot gas cools and contracts.

OBSERVATIONS.—Study the oxygen gas as follows:

1. Is the gas colorless and transparent?

2. Is the gas odorless?

3. Thrust a splinter of wood into the bottle of gas and then withdraw it. Did anything happen?

4. Kindle the splinter by holding it in the flame of the Bunsen burner, and then observe how it burns in the air. Blow out the flame on the

burning splinter. Is there a glowing ember on the end of your splinter? If so plunge the glowing ember into the jar of oxygen gas. Observe the effects. Remove the burning splinter and make it glow again and replace in the jar of oxygen. Repeat the act as many times as possible. Is the behavior of the glowing ember in the jar of oxygen different from its behavior in the air? Is the supply of oxygen in the jar finally exhausted? How do you know? Did the oxygen take fire and burn, or was it the stick that caught fire and burned? In which case was the light and heat more intense, when the splinter burned out in the air or when it burned within the jar of oxygen? In which case was the rate of combustion the greater, within or without the jar?

5. Pour some lime water into the second jar of oxygen, replace the cover and shake the lime water up and down through the oxygen gas. Do you note any change in the color of the lime water? If no change in color takes place, plunge in a glowing splinter and allow it to burn keeping the bottle partly closed with the glass cover while the process of combustion is taking place. Withdraw the splinter when it is extinguished. Again shake the lime water up and down through the gas in the bottle. Note the change in color. Lime water is used as a test for carbon dioxide gas, and the milky appearance indicates the presence of this gas. If you were given two bottles, one containing carbon dioxide and the other oxygen, how would you tell which was carbon dioxide and which was oxygen?

6. Wrap one end of the piece of wire about the lump of charcoal and using the other end of the wire as a handle try to burn the charcoal in the flame of the Bunsen burner. Does the charcoal take fire and burn with a flame? Thrust the glowing piece of charcoal into the third jar of oxygen. Observe what happens. Does it burn more readily out in the open air or in the jar of oxygen? Was carbon dioxide formed? Prove your answer by using some lime water. When charcoal, which is nearly pure carbon, is burned in oxygen what gas is formed? Did the carbon dioxide thus formed help or hinder your flame? Learn to draw your conclusions from what you actually see while doing the experiment, and you will seldom conclude wrongly. If you are in doubt, repeat the experiment or that part of the experiment concerning which you are doubtful.

7. Could you prove that paper contained carbon by burning it in a jar of oxygen and then testing the new gas thus formed with lime water? Try it using the fourth bottle of oxygen. Record your results.

8. Heat one end of a piece of picture wire and touch it to a piece of sulphur, and observe what takes place. Repeat and endeavor to thrust the wire with the burning sulphur into your fifth jar of oxygen. Observe closely the effects on the burning sulphur. When the sulphur burned off what happened to the wire? Did it in turn take fire? If it did not, remove the wire from the jar, reheat and recoat the wire with burning sulphur and thrust it again into the jar and thus endeavor to kindle the wire and cause it to take fire and burn. Does the sulphur burn more

readily in air or in the bottle of oxygen gas? When sulphur burns in oxygen, the sulphur joins with the oxygen and forms sulphur dioxide. Remove the glass cover from the bottle and cautiously note the odor and determine whether it is the same as the odor given off by the sulphur when it is burned in air. This characteristic odor may be considered a test for sulphur dioxide. When the iron burned in oxygen, the iron also united with the oxygen, and iron oxide was formed. Iron oxide is usually called iron rust. If iron rusts when it is exposed out of doors, whence comes the oxygen? When you kindle a fire and it burns, whence comes the oxygen that feeds it? Do you know whether the air is made up of pure oxygen, or is mixed with other gases? Give reasons for your answer. Is this a fortunate or an unfortunate condition? Explain. Iron, oxygen, sulphur, and carbon are *simple substances* or *elements*, for they cannot be broken up into simpler substances. When two or more elements unite to form a new substance they make a *compound*. When iron and oxygen unite to form iron rust a compound is formed. The chemical name for iron rust is iron oxide, which means that this compound is a union of iron with oxygen. Name two other compounds that were made in your study of oxygen in this experiment.

CARBON DIOXIDE

Object.—To prepare carbon dioxide and study its relation to a burning substance.

Apparatus.—Ninety cubic centimeters or 6 ounce bottle fitted with a two hole stopper. Safety funnel. Glass tubing. Two pieces of rubber tubing, 4 inches each. Pneumatic trough. Four wide mouth bottles and cover glasses.

Materials.—Small marble chips. Dilute hydrochloric acid. Wooden splinters. Lime water. Candle. Wire, 12 inches. Test-tube.

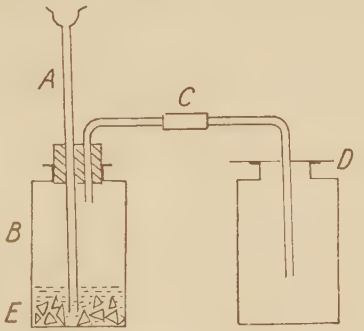


Fig. 8.—Apparatus for making carbon dioxide.

Procedure.—Have the instructor show you how to make a right angle bend in a glass tube. Study the accompanying diagram and arrange your apparatus exactly as there shown. Is your thistle tube so placed as to be within one half inch of the bottom of your bottle? Have the instructor inspect your set up and note the criticisms or suggestions passed upon your work.

Preparation of the Carbon Dioxide.—After having your apparatus inspected pour enough water into the safety funnel nearly to cover the marble and add dilute hydrochloric acid drop by drop until you notice

some bubbles escaping from the surface of the pieces of marble. If the evolution of the bubbles is too slow, add some more acid in small quantities. Always be patient and painstaking when doing experimental work whether in the school laboratory or in the home. You will learn more from one experiment well done than from many hastily and poorly performed. Learn to record in a simple manner the things that you do and see. Learn to draw the right conclusions from your results. Draw your own conclusions. Consult with books and your instructor whenever you think necessary. Place the free end of the delivery tube into a wide mouth bottle which is partly closed with a piece of paper or cardboard. Hold the end of a glowing splinter just inside the mouth of the bottle. Does the glow finally go out? Relight it and try again. Is the bottle full of carbon dioxide? What makes you think so? Fill, cover, and set aside five bottles of the gas.

Observations.—Study the carbon dioxide as follows:

1. Remove the cover of the first bottle and note the color and odor of the gas.

2. Thrust a flaming splinter into the bottle of gas. Does carbon dioxide gas support combustion?

3. Thrust some burning paper into the gas. Is carbon dioxide gas a good extinguisher of flames?

4. Pour some lime water into the second jar and shake. Record your observations and conclusions.

5. Light a candle and set it on the table. Pour the gas from the third bottle over the flame of the candle. Is the gas heavier or lighter than air? Give reasons for your answer. Would carbon dioxide be a good gas with which to fill balloons? Why?

6. Uncover the fourth bottle and using the hot flame of a Bunsen burner try to set fire to the carbon dioxide gas. Can you get the gas to burn? Name a gas that will support combustion. Name a gas that will not support combustion. Which gas would you use to extinguish fires?

HYDROGEN

Object.—To prepare hydrogen gas and to study its relation to a flame.

Apparatus.—Same as that used for making carbon dioxide.

Materials.—Pieces of zinc. Dilute hydrochloric acid. Splinters of wood. Matches.

Procedure.—After placing a layer of zinc on the bottom of the bottle set up the apparatus as shown in the accompanying figure. See that the safety tube comes within one half inch of the bottom of the bottle and that the right angle tube sticks through the cork at least one quarter of an inch. Be sure to see that the apparatus is air tight.

Preparation of the Hydrogen.—Have the instructor inspect your apparatus. Add enough water to touch the bottom of the safety tube and then add about one half as much dilute hydrochloric acid. *Have*

no flames and light no matches near your hydrogen generator. When the stream of bubbles slows up, add some more acid by pouring it down the safety funnel. Collect three bottles of the gas by displacing water, being sure to cover them well before removing from the pneumatic trough. Set the bottles aside mouth downward upon the glass covers.

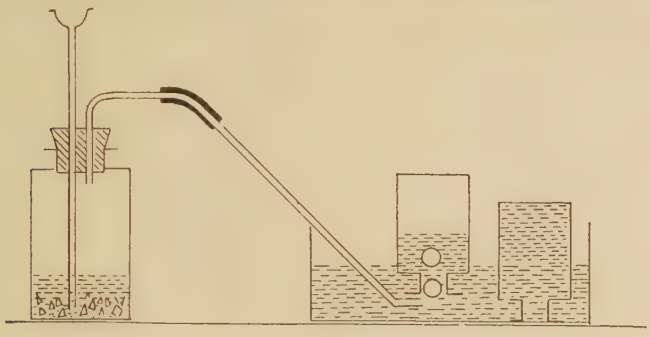


FIG. 9.—Apparatus for making hydrogen.

OBSERVATIONS.—Study the hydrogen as follows:

1. Take hold of the bottom of the first bottle and while holding the mouth downwards, thrust a flaming splinter up into the gas. What

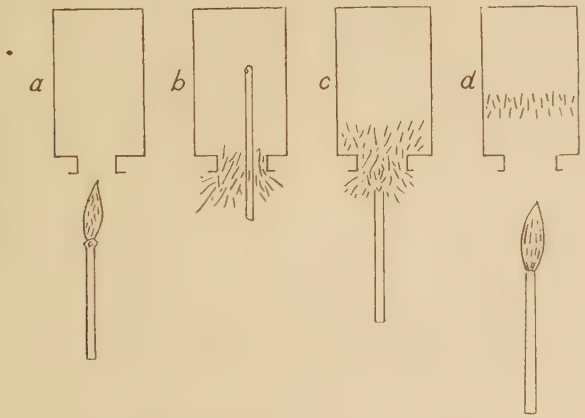


FIG. 10.—Showing what takes place when a flaming splinter is slowly introduced into a bottle of hydrogen and then slowly withdrawn.

happens to the gas? What happens to the flame on the splinter as it is passed up into the gas?

2. Read the directions in 1 a second time and repeat the experiment, and see if you can make better and closer observations than you did the first time. Did the flame on the splinter go out? Did the gas

burn? Was water vapor formed on the inside walls of the bottle as the hydrogen gas burned? Water is a *compound* made of hydrogen and oxygen. Where did the oxygen come from that united with the hydrogen to make the water?

3. Take the third bottle of hydrogen, mouth downwards, and see if you can pour the hydrogen upwards into the second bottle. Now bring a lighted taper to the mouth of the second bottle. Did the hydrogen pass up into the second bottle? If not, repeat the experiment, using greater care. Is hydrogen lighter than air? Give reasons for your answer. Is hydrogen gas a good gas to use in balloons? Is hydrogen a safe or a dangerous gas to use in balloons? Give your reasons.

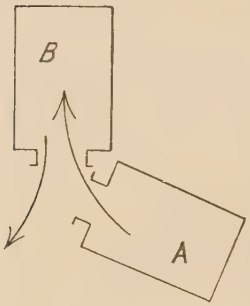


FIG. 11.—Bottle *A* contains hydrogen; bottle *B* contains air; arrows show path taken by the hydrogen as it "pours up" into bottle *B*, and the path by which the air leaves bottle *B*.

4. Remove the long glass tube and fasten in a right angle tube, the free arm of which has been slightly closed, as shown in the figure, by gentle heating in the flame of the Bunsen burner. Look at the zinc pieces and observe if the bubbles of hydrogen are being set free in large numbers; if they are not, add some more acid and wait until it acts on the zinc. *Allow the hydrogen gas to escape through the partly closed end of your new delivery tube for two or three minutes.* Set the test-tube down over the upright end of your delivery tube and allow it to remain there long enough to fill up with hydrogen.

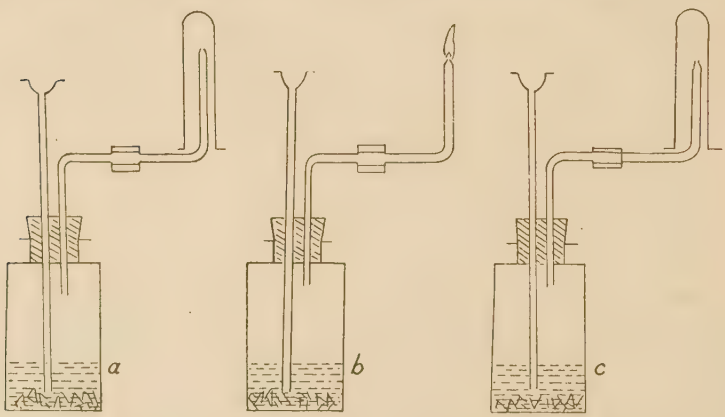


FIG. 12.—(*a*) Shows how to place test-tube when collecting hydrogen for testing. (*b*) Shows how to light the jet when you have the proper test. (*c*) Shows how to extinguish the flame.

Holding the test-tube upside down, remove it from the neighborhood of your apparatus and bring a lighted match to the mouth of test-tube. *If*

there is a sharp explosion, repeat the test until there is only a very slight puff. Now bring a flame to the end of your delivery tube. Hold a dry wide mouth bottle over the flame. Does the inside of the bottle become clouded over with water vapor? Whence came this water? Explain. In what manner is hydrogen different from oxygen and carbon dioxide? How shall we extinguish the flame of burning hydrogen? Bring a test-tube down over the flame so as to shut off the supply of air. What happens? Explain.

There are many gaseous substances that behave like hydrogen. These gases will not support combustion as oxygen does, but they will burn in the presence of oxygen. Such gases and vapors are called fuels. They are used in our homes for lighting, heating, and cooking purposes. The most common are coal gas, natural gas, and vapors from gasoline and kerosene. Can you think of other gaseous materials that may be used as fuels? Make a list of gaseous and vaporous materials that may serve as fuels, including those mentioned above.

AIR

Object.—1. To study air and its relation to a burning substance. 2. To discover which portions of the air aid the process of combustion, and which hinder it.

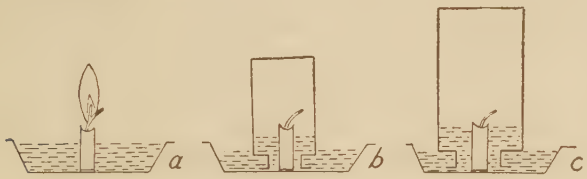


FIG. 13.—Determining the amount of oxygen in the air.

APPARATUS.—Two wide mouth bottles, one small and one large. Shallow pan. (If the experiment is performed at home, a drinking glass, a Mason fruit jar, and a dinner plate may be used.)

MATERIALS.—Candle, two inches long. Matches. Some water.

PROCEDURE AND OBSERVATIONS.—(1) Set the candle upright in the center of the pan and pour in water to a depth of one half an inch or so (Fig. 13). Light the candle and allow it to burn up well. Invert the small wide mouth bottle and set it over the candle as shown in Fig. 13. Note what happens. How high does water rise within the bottle? Blow out the stale air in the bottle and repeat the experiment two or three times with fresh air and observe whether the water rises to about the same height for each trial. Repeat the experiment several times with stale air left in the bottle. Does the stale air support combustion? Does fresh air support combustion? Explain why fresh air supports combustion and stale air does not.

2. Repeat the experiment with the bottle which is two or three times as large. Does the flame burn for a longer time? Give reasons for this. Do the various trials show that there is only a certain amount of oxygen in the air? Does the water rise about one fifth of the way each time? Repeat the experiment if you failed to make this observation. What part of the air is oxygen? The remaining portion which we have called stale air is nitrogen containing some carbon dioxide and the water vapor. The carbon dioxide is soon taken up by the water, leaving within the bottle almost pure nitrogen gas. Does this gas aid or hinder combustion? Give reasons for your answer If the air is one-fifth oxygen by volume, what part by volume is nitrogen gas? Which of these two elements supports combustion?

Why the Fire Burns.—The foregoing experiments teach us that in order to have the fire burn continuously we must have at least two substances present: *a constant supply of oxygen, and some other substance to serve as a fuel.* When either one of these materials, oxygen or the fuel, is exhausted, the fire cannot exist. Also during the burning process we found that new substances were produced and that heat and light were released. When carbon was burned it united with the oxygen, forming carbon dioxide. When hydrogen was burned it united with the oxygen, forming water. Such substances as oxygen, carbon, and hydrogen are called elements, for the reason that they never have been broken up into simpler substances. But when two or more of these elements unite, such as carbon and oxygen to form carbon dioxide, we say a *compound* has been formed. A compound may be broken down into simpler substances; for example, we may break carbon dioxide down into oxygen and carbon. Such a union of two or more elements to produce a compound is called a chemical union.

Oxidation. Two Kinds, Slow and Rapid.—When any element unites with oxygen, we say the process of oxidation has taken place. When a nail or an iron bar is exposed to the weather it rusts—that is, it unites with the oxygen, forming iron rust, or, as a chemist would say, iron oxide, because there is a chemical union between the iron and the oxygen of the air to form the compound which you call iron rust. Now there are two kinds of oxidation, slow and rapid. When burning sulphur on the end of the wire was lowered into the jar of oxygen, we

observed that the sulphur burned vigorously and gave off considerable heat and light during the formation of sulphur dioxide. When the sulphur had completed its burning, we discovered that the wire started to burn, and it too gave off considerable heat and light during the formation of iron oxide. In order to get the sulphur to unite with the oxygen, we had to heat it in the flame of the Bunsen burner. Cold sulphur or sulphur at the temperature of the room will not unite with the oxygen, and so it is necessary to heat it to a temperature which is called the kindling temperature of sulphur before it will burn, that is, unite with the oxygen to form sulphur dioxide. During the burning of sulphur the iron became so strongly heated that it finally reached the kindling temperature for iron, took fire, and burned vigorously, uniting with oxygen so rapidly that heat and light were given off during the process. Such rapid oxidation as this is known as *combustion*. When a piece of iron rusts, the union with the oxygen takes place at a temperature much below the kindling temperature for iron; indeed, it takes place so slowly that we are never aware of the heat that is being given off. In fact the amount of heat that is released during any second of time is too small to make itself known to our senses. Such slow oxidation is known as *decay*. Therefore when oxidation occurs at or above kindling temperature for a given substance, *rapid oxidation* or *combustion* occurs. When oxidation takes place below the kindling temperature, the process is known as slow oxidation or *decay*. Rapid oxidation or *combustion* is accompanied by the release of heat and light, while slow oxidation or *decay* never develops enough heat at any time to produce light.

Substances That Do Not Support Oxidation.—The experiments also pointed out to us that such substances as carbon dioxide and nitrogen will not support combustion; in fact, when either of these substances replaced oxygen, the flame was immediately extinguished. We also observed that these gases could not be used as fuels with which to feed the flame. This is not an unfortunate matter. The inactive nitrogen, which we found makes up four-fifths of the air, serves a very useful purpose as a dilutent for the oxygen. For if the air were pure

oxygen, fires, when once started on the earth, would become unmanageable and exceedingly difficult, if not impossible, to extinguish. Carbon dioxide is very effective for extinguishing fires, and since it is so easily made, it is used by fire companies in our cities and villages for extinguishing fires. Indeed, we shall later learn that nitrogen and carbon dioxide gases are used by plants in building up the various tissues and structures of their bodies which provide us with food and clothing, and thus the things in nature that seem to be of little use in some instances are of vital importance in others.

Controlling Fires. Camp Stove. Drafts and Dampers. When we build a camp fire or bonfire, the only means we have of regulating it is by the amount and kind of fuel that we lay upon the fire. If we pile on a large amount of brushwood or other combustible materials, we have a large fire. If we place fuel materials on the flames piece by piece, we are able by this means of regulation to produce a fire quite suitable to our demands. How-

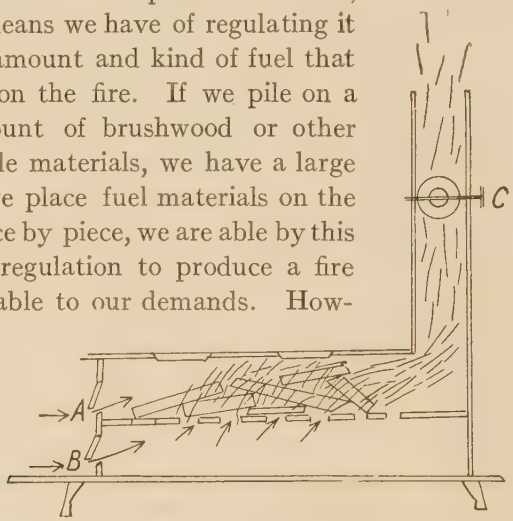


Fig. 14.—Camp stove.

ever if we use a camp stove similar to the one shown in the figure, we are able to regulate the fire from two sources, the amount of air that reaches the fire and the amount of fuel that is placed upon it. By adjusting the drafts *A*, and *B*, and the damper *C*, Fig. 14, we regulate the supply of oxygen that passes up through the fire. By closing the draft, *B*, we shut off all supply of oxygen that passes up and through the burning materials, and thus slow down the fire considerably. The air entering through the upper draft *A*, admits enough oxygen to consume the combustible gases and vapors that are given off

by the heated fuels; otherwise these gases and vapors collect in the stove and give rise to explosive mixtures that may cause trouble. The damper, *C*, that is located in the chimney, is constructed with a hole in its center in order that the flow of gases up the chimney can never be entirely shut off. Thus when the over draft, *A*, is slightly open, and the check damper in the chimney is partly open, it is unlikely that explosive mixtures of gases will collect in the stove. Similar means are used to regulate the air supplied to fires in stoves, furnaces, gas burners, in fact, in all devices in which flames and fires are employed.

Accidental Fires and Safety First Principles.—We have learned that a fire must have a constant supply of oxygen and fuel materials, and that, should either of these two factors become exhausted, the fire is extinguished. We may employ this knowledge in two ways—to make a fire or to extinguish a fire. When we build fires we must supply oxygen and fuel; when we wish to extinguish fires we must shut off the supply of oxygen or take away the fuel. When a person's clothing takes fire we have the problem of extinguishing the fire. Here we must act quickly and rightly, for delay and ignorance of what to do will cost the life of the person so endangered. In this case the person's clothing serves as the fuel, and the surrounding air provides the supply of oxygen. We must then act immediately and do one of two things—tear off the burning clothing, if possible, or smother the fire by wrapping about the body any *woolen* cloth or garment within reach. Never try to smother a fire with a cotton cloth, because cotton will burn. Running is the worst thing that can possibly be done, since it fans the flames. One effective way of smothering is to throw to the floor the person whose clothing is on fire and cover him with a rug or other woolen material, wrapping it closely about the neck and shoulders and downward toward the feet in order *to keep the flames from the face.*

Most fires are small in the beginning; therefore this is the time at which they may be easily extinguished. We must act quickly, but excitement may make us do exactly the wrong thing. Therefore it is necessary that we study out in advance,

when there is no fire, what should be done in case we were confronted with a fire. Then we shall not need to stop to think, if we find ourselves face to face with sudden danger. Small fires can be smothered easily with a carpet or woolen blanket. If oil or grease takes fire, the fire may be effectively extinguished by being covered with flour, sand, or dirt. Water is one of the best extinguishers of fires that we have, if we always

FIG. 15.—The wrong way to use a fire extinguisher. (*U. S. Bureau of Standards, Circular No.* 75.)

remember to add the water to the burning fuels and not to the flames that flash up above the burning substance. The water is changed to steam by the hot coals of the burning substance; this steam takes the place of air and thus shuts off the supply of oxygen. Again, wet fuels are below the kindling temperature of the fuel, and therefore it is the burning materials, instead of the flames, which should be drenched and smothered with a liberal supply of water.

Fire extinguishers are coming into common use. Factories, warehouses, and stores are generally provided with the hand type

of fire extinguisher. There are various designs of this sort of extinguisher on the market, and all homes should be provided with some good type placed at convenient points and within plain sight and easy reach. Every member of the family, including visitors and servants, should be taught how to use them. Fires break out suddenly and generally take one entirely by surprise. In the hurry of the moment one must

FIG. 16.—The right way to use a fire extinguisher. (*U. S. Bureau of Standards, Circular No. 75.*)

not have to wait to read directions telling how to operate the fire extinguisher. One must know in advance exactly what to do. Always remember that whether water or an extinguisher is used, the fire must be attacked at *its base, the place where the flame starts*. It is the burning materials that must be treated with the water or fluids from the extinguisher and not the flames that arise from the fire.

Projects

1. (*a*) To show that water is a compound by decomposing it into two simpler substances.

(*b*) To apply tests to these simpler substances in order to identify them as hydrogen and oxygen.

Suggestions.—Use Hofman's apparatus, Fig. 17, and consult texts on physics and chemistry concerning its operation.

2. To show the presence of carbon dioxide in our exhaled breath.

3. To demonstrate the construction and operation of a fire extinguisher that employs carbon dioxide. Figure 18.

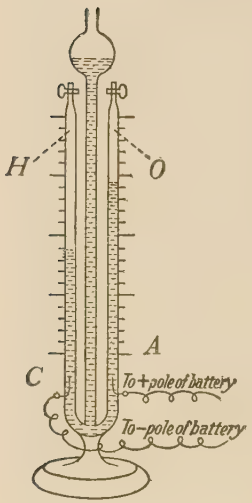


FIG. 17.—Electrolysis of water. (*From Tower, Smith, Turton, and Cope's Physics.*)

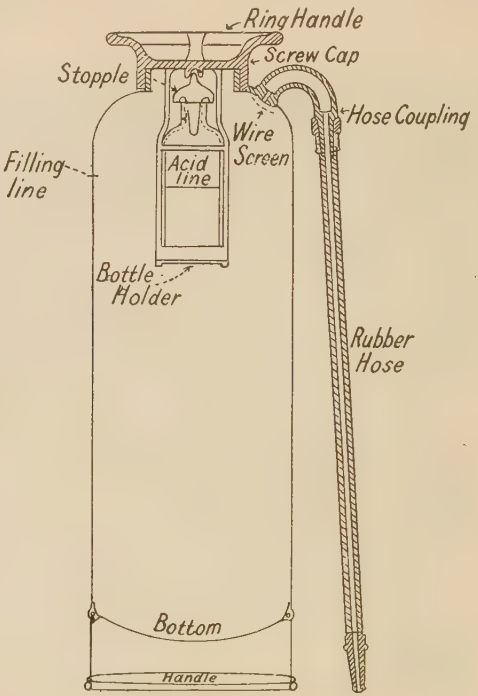


FIG. 18.—Sectional view of a soda-acid fire extinguisher. (*From U. S. Bureau of Standards, Circular No. 75.*)

4. To demonstrate the construction and operation of a Pyrene fire extinguisher. (If possible a small fire should be built in a safe place out on the campus and demonstrated upon.)

5. To shows how a woolen blanket, a woolen garment, or a rug is to be applied to a person in case the clothing were on fire. The demonstration should show both the wrong and the right way of carrying out this method of extinguishing the fire.

6. To make a study of the construction, operation, and useful application of the automatic sprinkler head. (Write a letter asking for such information to the General Fire Extinguisher Co., Providence, R. I.)

7. To make a map which shows the location of the fire alarm boxes and water plugs of the home community.

8. To write a short theme that "tells what to do" in case a fire is discovered in: (*a*) one's home, (*b*) a hotel, and (*c*) a theater.

9. To gather for ten consecutive days, newspaper clippings of fire hazards, and to make a wall chart that will set forth the facts found therein.

Suggestions for wall chart.—

Place	Date	Cause	Loss of property in dollars	Persons		Could the fire have been prevented? If so, who is to blame?
				Killed	Injured	

10. To demonstrate the construction and use of a pulmotor.

CHAPTER III

GENERAL EFFECT OF HEAT ON SOLIDS, LIQUIDS, AND GASES

Object.—To find means of applying heat to various solids, liquids, and gases in order to observe the effects produced and to learn the application of these effects to the arts of life.

Introduction.—Daily we are brought in contact with many puzzling situations that are difficult to account for. We see electric light globes made of glass and holding within them intensely heated wires, yet when pouring hot liquids into an ordinary glass we find that it invariably cracks or breaks into many pieces. The question why glass behaves so well in the one case and so badly in the other is only explained when we know the vital differences existing in the materials and construction of the two articles.

Again, why should some pendulum clocks lose time in summer and gain time in winter? Does the presence or absence of heat have anything to do with the operation of the clock? Again, why does a very cheap watch gain time in winter and lose time in summer, while a good watch is not so affected? What provisions are made in one watch that are not made in the other?

Again, on holidays we are in the habit of sending up large paper balloons. However, to do this we are very careful to have the air within the balloon well heated. Why do we take this precaution?

Have we ever observed the rising or lowering of the liquids in a thermometer and accounted for the conditions that produced the effects? It is the purpose of the following exercises to point the way to an intelligent understanding of the conditions that give rise to certain effects when substances are heated or cooled.

EXPANSION OF SOLIDS

Object.—1. To construct a piece of apparatus in order to study the effects produced in iron and copper rods when these are heated or cooled.

Apparatus.—Hammer. Saw. Square. Plane or sand paper. Bunsen burner or some source of heat such as candles arranged on a candle board.

Materials.—Board (*RS*), 3′ by 4″ by 1″. Three blocks, (*M*, *N*, *P*), 2″ by 4″ by 6″. Iron and copper rods, about 2′. Piece of stout iron wire (*B*) about 16′.

Procedure.—Study the arrangement of parts as shown in Fig. 19. Fix the rod (*A*) in block (*M*) by boring a hole in the block slightly smaller than the rod, and then driving the end of the rod into the hole. Nail the

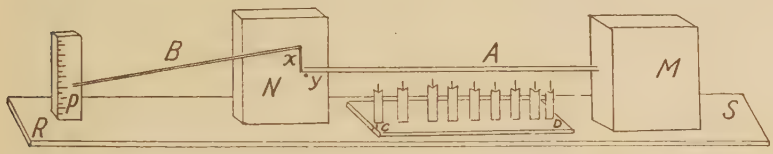


Fig. 19.—Materials that may be found in the home, and their arrangement to show the effects produced in iron or copper rods when heated or cooled.

board (*RS*) firmly to the blocks (*M* and *N*). Lay the apparatus back on its side and drive the nails (*X* and *Y*) half way into block (*N*) arranging the nails as shown in the illustration. Take the iron wire and bend it so as to have one long arm 15′ (*B*) and one short arm 1′. The bend must be a sharp right angle in order to rest accurately on (*X*), and on the lower end of the short arm pressing the free end of rod (*A*). Fasten to block (*P*) a ruler or a stick that is marked off into divisions. See that the blocks (*M* and *N*) are firmly fastened; if they are loose and shaky the apparatus will not show good results. Light one of the candles and allow the melted wax to drop at a spot in the center and one inch from the end of the board (*CD*). While the wax is still warm set one of the candles upright on the spot. Allow the wax to cool. The candle is now held fast to the board. Fasten on the remainder of the candles in a straight line and 1″ apart. Set block (*P*) and the ruler as shown in the illustration.

Observations.—Record where the end of the wire pointer rests against the ruler. Light every other candle and place the board and candles so that the flames just touch the rod. While the candle flames are heating the rod watch the end of the long arm of the pointer. Does it move up or down? Why? Light all the candles. Does the pointer move farther along the scale? Explain or give the cause of this movement by the pointer. How many spaces did the pointer move all together? Blow out the candles. While the rod is cooling watch the pointer. Explain what takes place.

Suppose the long arm on your pointer were still longer, would it have shown a greater or a smaller reading? If in doubt replace this pointer with one that has a 20″ arm and repeat the experiment, being sure to move the block (*P*) and the ruler out until the end of the pointer rest opposite the scale. Did the rod actually expand as much as the long end of your pointer moved, or did the movement of the long arm simply magnify the real amount of expansion in your iron rod? You will often find in various kind of instruments this kind of arrangement to magnify the effects that are actually produced.

Had your iron bar been made of copper or brass, what would the effects have been? If the other students who have made similar apparatus used copper or brass rods instead of iron, trade with them and repeat the experiment. What is your final conclusion regarding the effects of heat upon such solids as iron, brass, and copper? Do you know whether heat affects other solid substances in a similar manner? If so, give instances.

Describe the effects on telegraph and telephone wires as the seasons change from summer to winter. Account for the little spaces left between the ends of the iron rails on a railroad track? Find out if engineers make provision for expansion and contraction when they construct long iron bridges. In the large dictionaries look under the word *expansion* and see if you can find there the term 'expansion-joint' or 'expansion coupling.' Record and report what you find.

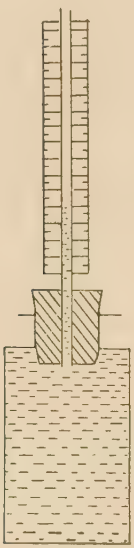


FIG. 20.—Apparatus for showing the expansion or contraction of liquids.

EXPANSION OF LIQUIDS

Object.—2. To construct a piece of apparatus in order to study the effects in a liquid when heated or cooled.

APPARATUS.—Glass bottle or flask fitted with a one-hole stopper and 12″ of glass tubing. Pan. A source of heat.

MATERIALS.—Hot and cold water. Some thread or rubber bands.

PROCEDURE.—If the ends of the glass tubing are fire polished, wet the tube with water and carefully work one end through the hole in the stopper. The glass tube should extend all the way through the cork, as shown in the illustration. If you have not a rubber stopper, select some soft cork that fits your bottle and work a hole through it with the sharp end of a round file. Using the other end of the file, with a twisting motion work the file forward and backward until there is a smooth round hole throughout the cork that is slightly smaller than your glass tubing. Using care fit the cork on one end of the glass tube. Fill the bottle

with water. Set the cork with its glass tube in the mouth of the bottle, using enough pressure to set the cork firmly in place. As you do this, the water will rise in the glass tube and should have a height of at least 2″ above the cork. Place a rubber band about the glass tube and adjust it so as to mark the level of the water within. Dry the apparatus with a clean towel, and then observe if all the connections are water tight.

Observations.—Set the bottle down to its neck in a pan of cold water. Observe the effect on the water level in the glass tube. Does the water level rise or fall? Adjust a second rubber band or thread to this new level. Set the bottle to the same depth in a pan of hot water. Observe the water level. Does a liquid expand or contract when heated? Write a statement which summarizes the effects produced in liquids when heated or cooled.

EXPANSION OF GASES

Object.—3. To construct a piece of apparatus in order to study the effects in a gas when heated or cooled.

Apparatus.—Glass bottle. One hole stopper. 18″ of glass tubing to fit stopper. Pan. Source of heat.

Materials.—Hot and cold water. Some thread.

Procedure.—Arrange the apparatus as shown in the illustration. Be sure to see that all connections are air tight.

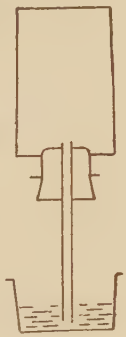


Fig. 21.—Apparatus for showing expansion and contraction in gases.

Observations.—Pour cold water over the bottle and observe the water levels in the glass tube, adjusting the thread to the new level. Did the air in the bottle expand or contract? Pour warm water over the bottle. What takes place? Did some bubbles of air escape? What is the cause of their escape? Write a statement which summarizes the effects produced in gases when heated or cooled.

General Effects of Heat on Solids, Liquids, and Gases.—The three foregoing experiments indicate in a general way the effects of all heating and cooling processes when applied to solids, liquids, and gases. We found that the copper and iron rods expanded and became longer when heated; when cooled, they contracted and grew shorter. These expanding and contracting effects were equally true of water and air when heated and cooled. Now if we had used silver or gold or other solids in the place of the iron or copper bars, kerosene or some other liquid in the place of water, and hydrogen or carbon dioxide gas for air, the same general effects would have been the

result. They would have increased in size with an application of heat, diminished when cooled.

Provision Made for Expansion and Contraction.—The variation in the size of bodies due to the presence or absence of heat must be seriously considered by engineers when setting the rails for a railroad track, running wires for telephone and telegraph systems, and in all similar constructions where materials are exposed to the severe changes of temperature that take place as the seasons change from summer to winter. Even the heating and cooling effects that take place during the change from day to night must be taken into account and provided for. Indeed, when the farmer builds a wire fence, he

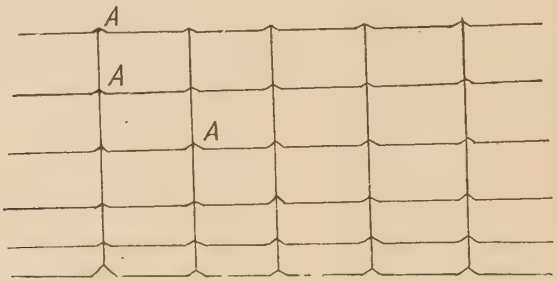


FIG. 22.—A wire fence so manufactured as to allow for the heating and cooling effects.

must make provision for the severe contracting effects that will take place during the winter months. Sometimes the manufacturer of wire fences will make these provisions in the fence materials during the manufacturing process, as shown in Fig. 22. He will crimp the steel wires as indicated at (*a*) in the illustration. This crimp allows the wire to straighten somewhat when the low temperatures of winter cause it to contract and shorten, and, when the hot days of summer return, the spring-like action of the crimped portions takes up the slack wire due to expansion. Thus the fence keeps its shape during the seasonal changes.

When the plumber installs a hot water or a steam heating plant in a building, he must make provision for the expansion and contraction of the steam and hot water pipes that will take place daily when the plant is in operation. If the plumber

does not take these matters into consideration, serious consequences will ensue involving not only loss of time but the destruction of property and in many instances even of life.

Useful Applications of Expansion and Contraction.—When a bridge builder wishes to fasten the several parts of a bridge firmly together, he uses red hot rivets which are placed in the

FIG. 23.—Truss bridge showing roller support at one end. (*From Tower, Smith, Turton, and Cope's Physics.*)

holes and pounded down while hot. When the rivet cools, it contracts and thus draws the parts more firmly together, and consequently a very solid construction is the result. But on the other hand the bridge builder must not forget to make provision for the expansion and contraction produced daily in his bridge when it is completed. He places it, therefore, upon iron

FIG. 24.—A blacksmith fitting a tire to a wheel.

rollers in order that it may lengthen when heated, and shorten when cooled. If he did not do this, the bridge would tear itself free from its supports.

The blacksmith makes use of the expanding and contracting properties of iron when he sets a tire on a wheel. The tire must be made slightly smaller than the wooden rim of the wheel. How is he, then, to set the tire in its proper place? If possible interview a blacksmith and make arrangements to visit him at a time when this work is in progress. What would happen if he

made the tire considerably too small, heated it, and then set it upon the wheel? Consult the blacksmith upon this point and see if your conclusions agree with his. Thus in the arts and industries we see the bridge builder making use of the forces due to expansion and contraction to draw his bridge more firmly together, and the blacksmith, to set his tire. But the farmer, the plumber, and the engineer who builds the railroad or telephone and telegraph lines must all make provision to avoid the disastrous results that may arise should they neglect these forces resulting from the expansion or contraction of the materials that they employ.

FIG. 25.

FIG. 26.

Unequal expansion of metals. (*Tower, Smith, Turton, and Cope's Physics.*)

The Thermostat.—All solids do not expand and contract alike for equal changes of temperature. Copper expands more

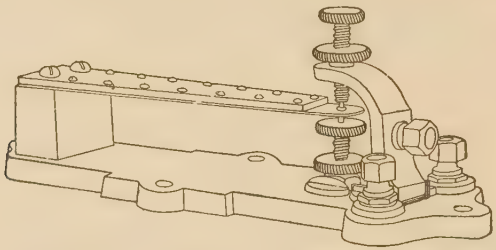


FIG. 27.—Thermostat. (*From Clute's Experimental General Science.*)

than iron when subjected to the same heating effects. This is illustrated strikingly when a strip of copper is riveted firmly to a strip of iron. When this compound bar of iron and copper is heated, the greater amount of expansion is produced in the copper side of the bar, which thus is bent or bowed, Fig. 26. In such a case the greater expanding solid, the copper, is on the outside of the curve, while the iron is on the inside. What happens when the compound bar is placed in cold water or upon a cake of ice? When this compound bar is set in a frame and properly adjusted, it may be employed to bring about the ringing of "warm" and

FIG. 28.—The compensated balance wheel.

"cold" bells in hothouses, to regulate the furnace drafts, and to operate metal thermometers. Instruments that employ the compound bar for the regulation of temperatures are called thermostats.

Projects

1. To study the construction and use of a compensating pendulum.
2. To study the balance wheel of an accurate watch in order to discover the need for a compensated balance wheel.

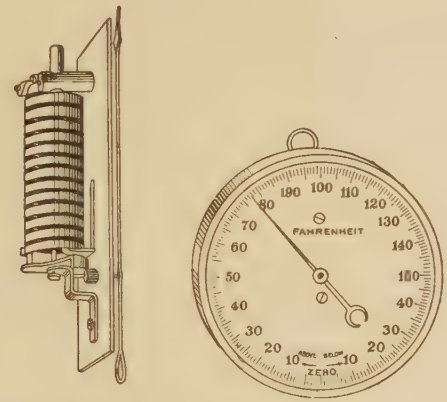


FIG. 29.—Metallic thermometer. (*From Tower, Smith, Turton, and Cope's Physics.*)

3. To study the construction and operation of a dial thermometer.
4. To locate the thermostat in a modern self regulated heating system and to work out its construction and method of operation.
5. To build a simple thermostat and to install it in the green house, or basement, or garage, so as to ring a "cold bell" in order that preventive means may be employed to avoid freezing of plants, water pipes, or radiators on automobiles.

CHAPTER IV

MEASUREMENT OF TEMPERATURE AND HEAT

Object.—1. To study the construction of the various kinds of thermometers and to learn their uses.

2. To find a means of measuring quantities of heat.

Introduction.—If we place one hand in a vessel of iced water and the other in moderately hot water, we at once perceive a strong contrast. Now if we should suddenly plunge both hands into a third vessel of water of medium temperature, we would have a confusion of results, for the water would feel cold to the hand withdrawn from the warm water and warm to the hand withdrawn from the cold water. Again, a person who has been out of doors may on entering a room declare the room to be quite warm and comfortable, while a person who has been sitting in the room for some time may declare that the room is uncomfortably cold. From such observations we conclude that *hot* and *cold* are terms of comparison only, and that our bodies are very unreliable indicators of the degree of heat that surrounds us. Difficulties of this sort have brought about the construction and use of instruments known as thermometers. Thermometers are so constructed as to make use of the fact that practically all bodies expand when heated.

THERMOMETERS

Object.—1. To study the construction of a chemical thermometer.

2. To compare the scale on a Fahrenheit thermometer with the scale on a Centigrade thermometer.

3. To find a method of changing Fahrenheit readings to Centigrade readings, or Centigrade readings to Fahrenheit readings.

Apparatus.—Two chemical thermometers, one Centigrade and the other Fahrenheit. Iron stand with ring and wire gauze, two beakers, Bunsen burner.

Materials.—Ice. Water.

Procedure and Observation.—(*a*) Examine the thermometers and compare their parts. Observe the bulbs filled with liquid. How far up

does the little thread of mercury or liquid rise in the stem? Hold your fingers on the bulb and observe the effect. Explain the cause of these effects. Place the bulbs in some cold water and explain the effects that are produced.

(*b*) Fill one of the beakers with some crushed ice and place the bulbs of the two thermometers in the center of the mass of ice. What happens? Read the temperatures indicated on each thermometer every few minutes. Record the readings on each of the thermometers. At what temperature does ice melt on a Fahrenheit thermometer? On a Centigrade thermometer? Hang the two thermometers on a support so that the two bulbs extend below the surface of some water in a beaker, Fig. 30. Heat the water until it boils. What is the boiling point on each scale? At sea level the boiling points are near 212°F. and 100°C. Atmospheric pressure becomes less as we rise above sea level, and consequently the water boils at a lower temperature owing to the fact that the steam-bubbles are under less pressure and escape more easily. When we have an atmospheric pressure of 14.7 lbs. per square inch, the water boils at 212°F. or 100°C.

How many degrees are there between the freezing point and boiling point on each scale? How many degrees on the Fahrenheit are equal to one Centigrade degree?

Find the thermometer used in the schoolroom. What kind is it? Read the temperature. If it is a Fahrenheit thermometer, can you convert its reading into a Centigrade reading? Try it and report your method to your instructor.

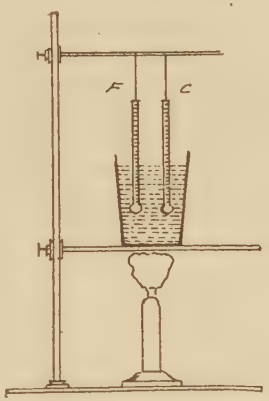


FIG. 30.—Comparing a Centigrade with a Fahrenheit thermometer.

Hold the bulb of the Centigrade thermometer under your tongue for three or four minutes and observe the temperature. Convert the reading to a Fahrenheit reading. Test your answer by holding the bulb of a Fahrenheit thermometer under your tongue.

Of what use is a thermometer to a physician? To candy or bread makers? To a florist or an agriculturist? To the dairyman? To the house wife?

HEAT UNITS

Object.—1. To learn whether a pound of iron or a pound of water carries the greater quantity of heat.

2. To find a unit of measure for heat.

APPARATUS.—Three large tin cans, two quart size; a one-pound iron weight or ball; a source of heat, thermometer, scales.

MATERIALS.—Water and some wire or twine.

PROCEDURE AND OBSERVATION.—Weigh the ball. Place water equal to the weight of the ball in each of the three cans. Fix a wire or string to the ball and lower it into one of the cans of water, Fig. 32. Heat the ball and water until the water begins to boil. Will the ball and boiling

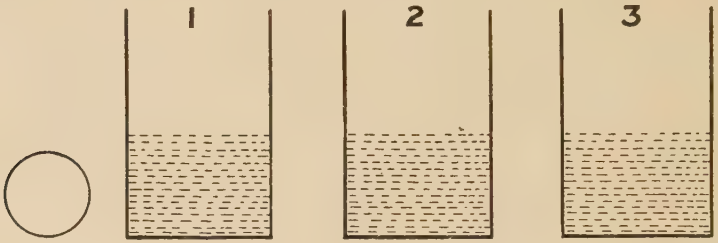


FIG. 31.—Iron ball is equal to weight of water in each of the cans.

water have the same temperature? While the water and ball together are being heated find the temperature of the cold water in the other two cans. Remove the heat. Transfer the ball to the second can of cold water, and the hot water to the third can of cold water, Fig. 33. Stir the mixtures

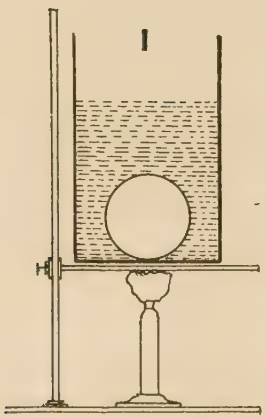


FIG. 32.

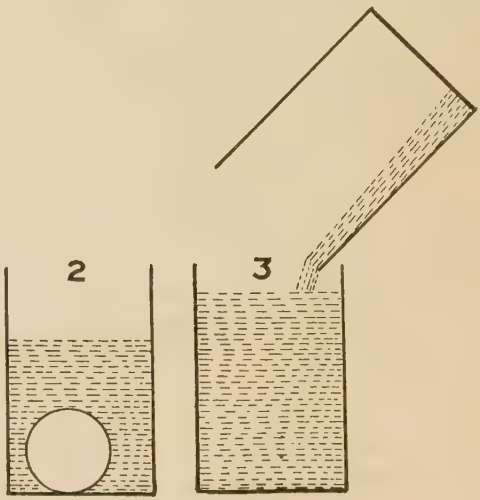


FIG. 33.

with your thermometer and note carefully which has the higher temperature. Which carried the greater amount of heat to their mixtures, the pound of iron or the pound of water? When a pound of water cools one degree Fahrenheit, it gives up a certain amount of heat. When it cools two degrees it gives up twice as much heat. The *amount of heat given up by one pound of water when it cools one degree Fahrenheit is called one British*

thermal unit (*Btu.*). When a pound of water is heated up one degree Fahrenheit it takes up one British Thermal Unit. Two pounds when heated 2°F. would take up 4 Btu. How many Btu. would be required to heat 10 lbs. of water 10°F.? How many Btu. would 10 lbs. of water give up when cooled 10°F.? Can a body ever give up more heat than it receives? Give reasons for your answer.

Necessity of a Standard Unit of Measure.—As every one knows, we measure the value of everything we buy and sell in terms of a unit which we call the dollar. Thus, we speak of the price of wheat as $1 a bushel, or the price of a suit of clothes as $40, the price of admission to a ball game as a half dollar or 50 cents. Before man made use of money, the value of an article was very uncertain. Even now a good trader may obtain a very worthy and useful article in return for something less worthy and useful, and do this sort of thing repeatedly in lands where money is unknown. In civilized countries the value of articles is closely calculated from costs paid for materials, labor, and operating expenses in terms of money, and thus certain articles have a price that is more or less uniform. As man becomes more civilized, he requires more accurate standards of measure for everything with which he comes in contact. He requires an accurate yard stick for measuring length, an accurate pound weight for measuring mass or weight of articles, a meter for measuring water, a clock for measuring time, a speedometer on his automobile for measuring velocity, a barometer for measuring atmospheric pressure; indeed, instruments of more or less accuracy may be found for measuring in some manner or other nearly every activity concerned with human welfare.

Necessity of Thermometers.—In the early history of man there was less need for instruments for measurement than there is at present. Today papers, magazines, books, letters, and other forms of communication carry the knowledge and information of one corner of the earth to the other. We must understand each other exactly. If we are to write or read books on the care and manufacture of dairy products, candy making, distillation, sugar making, bathing, fruit evaporating, hot water heating, refrigeration, and a thousand and one other matters, we must know the exact temperatures that yield or determine

the best results for each of the above activities. Hence the necessity of thermometers has become so widespread that a person who undertakes to do well must become accustomed to the use of such an instrument.

FIG. 34.

Invention of the Thermometer.—Many men have been credited with the invention of the thermometer. Drebbel, a Hollander, has been referred to more than any other, but to Galileo a great deal of the credit is due. In 1592 at the University of Padua in Italy, Galileo constructed his first thermometer. He was familiar with the facts of expansion of solids, liquids, and gases; and, since gases expand more than solids or liquids, he chose a gas as his expanding substance. His device was arranged like that shown in Fig. 34. Make one and study its operation.

Fahrenheit and Centigrade Thermometers.—The thermometer of Galileo was not a very convenient form, and therefore many changes were made in an endeavor to get a more useful form of instrument. In 1714 Fahrenheit of Danzig designed and brought forth our present form of mercury thermometer. The scale on his thermometer shows the freezing point of water at 32°F. and the boiling point at 212°F. Anders Celsius, Professor of Astronomy at the University of Upsala, proposed a scale in 1742 and called the freezing point of water 100°C. and the boiling point 0°C. These points were afterward reversed by Christine of Lyons in 1743. The result is that on this scale, known as Centigrade, 0°C. is set at the freezing point of water and 100°C. at the boiling point of water, with the space between these two points marked off into 100 spaces, each of which stands for 1°.

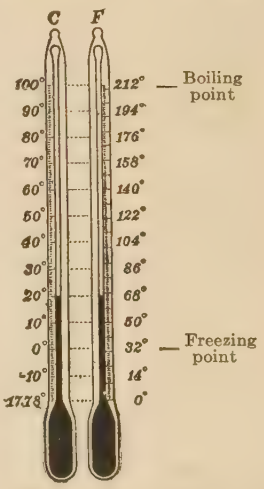


FIG. 35.—Comparison of Centigrade and Fahrenheit scales. (*From Tower, Smith, Turton, and Cope's Physics.*)

Comparison of Scales on Centigrade and Fahrenheit Thermometers.—The common household thermometer in the

British Empire and the United States is the Fahrenheit, while that used in all scientific pursuits and literature is the Centigrade scale. Thus a knowledge of the relationship of the two scales is a necessity. Examining the Fahrenheit scale we find 180° between the freezing and boiling points of water, while on the Centigrade scale there are 100°C. Hence 180°F. corresponds to 100°C. or 1.8°F. to 1°C. Therefore to convert any Fahrenheit reading to Centigrade degrees, subtract 32 from the Fahrenheit reading and divide the remainder by 1.8. To convert a Centigrade reading to a Fahrenheit we do the exact

FIG. 36.—A clinical thermometer used to take the temperature of the body. (*From Tower, Smith, Turton, and Cope's Physics.*)

opposite—that is, we multiply the Centigrade reading by 1.8 and add 32.

$$\frac{(F - 32)}{1.8} = C$$

$$F = 1.8 \times C + 32$$

Clinical or Fever Thermometers.—The temperature of the human body is not the same in all parts of the body, and so, to establish a common standard, doctors and physicians have accepted the temperature as taken under the tongue. From a great many readings a point 98.6°F. has been recognized as "normal health." If the temperature rises above or falls below this point, the delicate mechanism of the body is in some way out of order. Some people find that their individual temperatures are a trifle above or below the correct temperature. Fever thermometers (generally called clinical thermometers) should be left under the tongue one minute, two minutes, or the particular time for which the thermometer was designed. The tube is made in such a manner that while the mercury will rise in the tube as the temperature increases, it will not go back to the bulb after it is taken from the mouth. This is called a "self-registering" feature, and it is necessary after each observation to hold the thermometer firmly by the upper end with bulb downward and swing or shake it in such a manner as to force the mercury back toward the bulb.

Heat Units.—We learned in an earlier chapter that whenever the process of combustion took place, heat was released. When we burn any particular substance which may be used as a fuel, a *definite amount* of heat can be released, and we can never increase the amount of heat above this *definite quantity* for a given weight of the fuel. This definite quantity is known as the heating value of the fuel.

In order to measure heat we must have a standard unit of measure. The unit in common use is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. This unit of heat is called the *British Thermal Unit.* When speaking or referring to this unit engineers simply say B-t-u or write Btu. In order to measure units of heat, scales and a thermometer are the essential instruments, for it is necessary to know the weight of the water as well as the number of degrees of temperature change.

Since the amount of heat produced is not by any means the same for different fuels, it is necessary for an engineer to know definitely the heating value of the fuel which he is to use. Some fuels contain impurities that seriously lower their heating values, and if a manufacturer who used fuels had no means of testing for heat values, his operating expenses would be uncertain. To avoid losses in poor fuels, in every well-organized factory or industry in which large quantities of fuels are used, provision is made for the accurate measurement of the heating value of the various kinds and grades. For example, a pound of good coal has a heating value of about 13,000 Btu.; that is, a pound of coal has a heating value sufficient to heat 13,000 pounds of water 1 degree Fahrenheit. A pound of wood produces only about two-thirds as much heat as a pound of good coal.

The nations that use the metric system of weights and measures use the Centigrade thermometer, and for this reason they have established a standard unit of heat known as the *calorie. The calorie is the amount of heat required to heat 1 gram of water 1 degree Centigrade.* They also have a large calorie, which is the amount of heat required to heat 1 kilogram (1000 grams or 2.2 lbs.) 1 degree centigrade. The calorie is used in this country in all scientific schools and universities

and in most of our scientific magazines and books when quantities of heat are recorded or referred to.

Projects

1. To make a study of the construction, operating principles and uses of the various kinds of self-registering thermometers. (Illustrate your report with figures obtained from manufacturers' advertising literature.)

2. To obtain information concerning the methods employed in manufacturing thermometers. (Report your information in a theme entitled "How Thermometers Are Made.")

3. To set forth by means of drawings or a demonstration model the construction and operating principles and uses of the thermograph.

4. To obtain information concerning the construction and uses of metallic pyrometers.

5. To write a theme entitled "How the Potter Knows the Temperature of His Kiln."

6. To write a theme on "The History of the Development of the Thermometer."

7. To test with a standard thermometer the accuracy of the thermometers in use in the school and home and to set forth the results of the findings in the form of a report.

8. To write a set of instructions for the proper placing of a thermometer for recording true temperature conditions (*a*) in a living room and (*b*) out of doors.

9. To write a theme on "The Clinical Thermometer and Its Use as an Indicator of Bodily Health."

10. To write a theme on "The Thermometer and Its Uses in the Industrial World."

11. To write a theme on "The Thermometer and Its Use in the Art of Cooking and Preserving Foods."

12. To solve the following problems:

(*a*) Lead melts at 326°C. Find the corresponding temperature on a Fahrenheit thermometer.

(*b*) If mercury freezes at −39°C., find the corresponding freezing point on a Fahrenheit thermometer.

(*c*) Which is the higher temperature, 12°F. or −12°C.?

(*d*) If the lowest winter temperature at a given place is −30°F. and the highest summer temperature is 100°F., what are the corresponding temperatures on a Centigrade thermometer?

(*e*) The temperature of a school room is 69°. The temperature of a vessel of water is 140°. A person has a temperature of 103°. On a certain day during a rain storm a person observes a temperature of 11°. Which thermometer scale is referred to on each of the above occasions? Give reasons for your answer.

(*f*) One pound of good coal furnishes 13,000 Btu. How many pounds of coal will be required to heat 100 lbs. of water from 50°F. to 212°F.?

(*g*) 1. One cubic foot of natural gas gives 1000 Btu. The gas is burned in a heater that is 60% efficient. How many cubic feet of gas will be required to furnish enough heat to warm 20 gallons of water for the bath from a temperature of 40°F. to a temperature of 92°F.? One gallon of water weighs 8.33 lbs.

2. Find the cost of heating the water if a charge of 55¢ per 1000 cu. ft. is made.

CHAPTER V

THE TRANSFER OF HEAT

Object.—To study the various methods of transferring heat and to discover means for controlling them.

Introduction.—Since early childhood we have learned many things about heat. If we place a hot flatiron aside upon an iron stand or a brick, we know that the iron stand or brick will become heated, because some of the heat will pass from the hot flatiron into the iron stand or brick. If we allow the flatiron to remain on the stand for a few hours and return to it, we shall find it no longer hot but quite cold; indeed, the flatiron and its iron stand will be no warmer than the other articles about the room. A plate of hot soup, a cup of hot tea, in fact, all hot articles of food are soon cooled, if they are allowed to stand for a short time. These facts and many more are made known to us through daily experiences; in short, it seems impossible to store up or preserve a quantity of heat as such for any great length of time. The heat escapes from us on every hand; in other words, it appears to be in a constant state of motion and interchange between bodies or passing off into space beyond our grasp. This motion or interchange of heat takes place in three ways which a common fire-place very well illustrates. If we place ourselves directly before the fire, we experience the sensation of warmth which is not due to the air, for if a screen be placed between us and the fire, the sensation of warmth disappears. Hence the heat has made its way through the space between us and the fire. This process of sending forth heat is called *radiation*. Again, suppose we grasp one end of an iron poker and thrust the other end into the fire. Shortly we shall find the end which we hold growing warmer and warmer; here the heat must have travelled up through the metal of the poker. This method of transferring heat from one part of a body to another is termed *conduction*. Lastly a third method

by which heat may be transferred may be observed, if we know that the air which passed through and near the fire became very much heated and passing up the chimney carried away heat. This carrying or conveying of heat from one place to another is called *convection*. Each of these three methods of transferring heat possesses certain peculiarities which will be the object of our study in the following experiments and demonstrations.

RADIATION

Object.—To study the radiation of heat by hot bodies and to find means of controlling it.

Apparatus.—Iron ball or weight. Iron ring stand. A piece of card board or a piece of paper large enough to encircle the ball without touching. Some iron wire. A source of heat.

Procedure.—Securely wrap the iron wire about the iron ball or weight and support as shown in the figure. Adjust the flame under the iron ball and allow it to heat for several minutes. Remove the flame.

Observations.—Slowly bring the palm of your hand toward the ball and note the effects as your hand draws near. Repeat the observation from all sides and from below. Does the ball send off heat in all directions? This method of sending forth heat is called radiation. Does a hot stove or a radiator containing steam or hot water emit heat in the same manner? Does the sun radiate heat? Do all hot bodies radiate heat? Give instances.

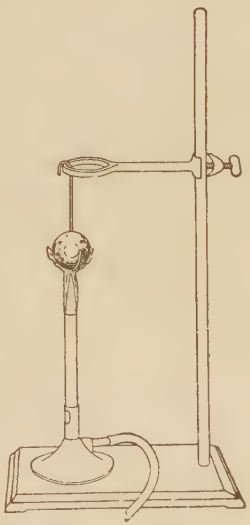


Fig. 37.—Arrangement of apparatus. (*From Ahrens, Harley, and Burns' Practical Physics.*)

Roll the piece of paper or cardboard into a cylinder and slip it up over the ball. Bring your hand toward the surface of the cylinder. Are the radiations of heat cut off? Does the cardboard cylinder act as a shield or screen to protect your hand from the radiant heat of the ball? May this be considered a method of controlling radiant heat? Suppose the hot ball were wrapped up in several layers of paper, or cotton, or flannel, would it cool off as rapidly as if it were not so covered? Do the flannels and furs that we wear in winter heat the body or keep the heat from escaping from our bodies? What is the purpose then of our winter clothing—to aid or prevent the radiation of heat from our bodies? Why do firemen and stokers of hot fires wear heavy flannel shirts even in summer time? When and why do we use a parasol?

CONDUCTION

Object.—1. To study the conduction of heat in solids.

2. To learn which solids are good conductors of heat and their uses as such.

3. To learn which solids are the best nonconductors and their uses as such.

Apparatus.—Bunsen burner or candle.

Materials.—6″each of iron and copper wire of the same size. Glass tubing. Wooden splint. One small cork. Small piece of asbestos paper 1″ by 2″.

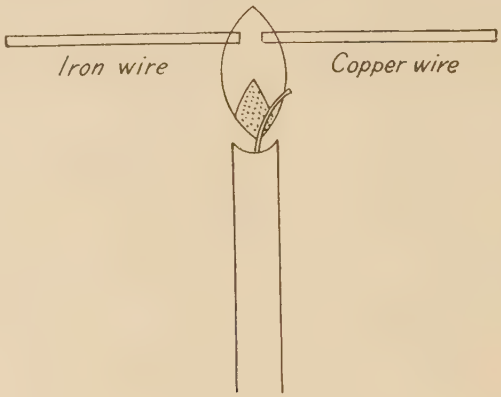


Fig. 38.

Observation.—Take the iron wire in your left hand and the copper wire in your right. Hold the ends of the wires between the thumb and finger and bring the free end of each wire into the flame of a candle as shown in Fig. 38. Observe which of the two wires is the first to transfer the heat to your fingers. Cool the wires by holding them in some water, dry them, and repeat the experiment and see if you get the same result. Which material, iron or copper, is the better conductor of heat? This method of transferring heat from one part of a body to another part of the same body, or from one body to another body when they are in contact, is called *conduction*. Repeat the experiment with an iron wire and a glass rod. Which material, iron or glass, fails to conduct heat? Which of these materials is a good conductor of heat? Which is a poor conductor of heat?

Repeat the experiment with an iron wire and a wooden splinter. What happens? Does the wood conduct any heat at all to your fingers? Is it a good or a poor conductor of heat? Look in the dictionary for the words *insulator*, *insulation*, and *nonconductor*. Can you find appropriate definitions?

Stick one end of your copper wire into one end of a cork. Wrap a piece of asbestos paper around the end of the iron wire. You now have a cork handle on your copper wire and an asbestos handle on your iron wire. Take hold of the handles and repeat the experiment. Do the cork and asbestos handles protect your fingers from the heating effects? Are cork

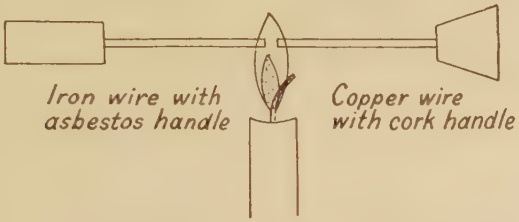


FIG. 39.—Are asbestos and cork materials good insulators?

and asbestos materials conductors or nonconductors of heat? Are cork and asbestos good insulating materials?

When the wires have cooled, hold the handles in the flame as shown in Fig. 40. Which of the materials takes fire and burns? Which of the materials, cork or asbestos, is the safer material to use as an insulator? Why do we put asbestos pads under hot flatirons and similar hot articles?

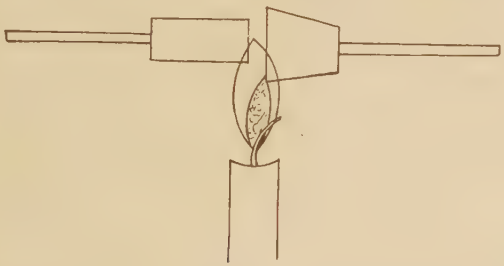


FIG. 40.—Which of the two insulators burns the more readily? Which of the two insulators would you use on the surfaces of hot pipes, furnace coverings, and similar surfaces?

Why not use cork pads? Why do we put wooden handles on stove pokers, soldering irons, teapots, stirring ladles, and curling irons? Name other articles on which you find insulating materials. Why are steam pipes packed in glass wool or asbestos? Does a hot body cool more rapidly when placed on an object of metal or when placed on wood? Explain. Which is the better nonconductor of heat, cotton or woolen fabrics? Explain why people prefer cotton fabrics as clothing materials in summer and in hot countries. Why do we use woolen and fur materials in winter and in cold climates? Does woolen clothing supply any heat to warm our bodies? Explain.

CONVECTION

Object.—To study the transfer of heat in liquids and gases.

Liquids

(*a*) Apparatus.—Large test tube. A source of heat.

Materials.—Some water.

Observations.—Fill the test tube two-thirds full of water. Incline the tube and apply heat to the upper portion of the water. Heat gently until the water boils. Does the water become heated at the bottom of the tube and burn your fingers? Is water a good conductor of heat?

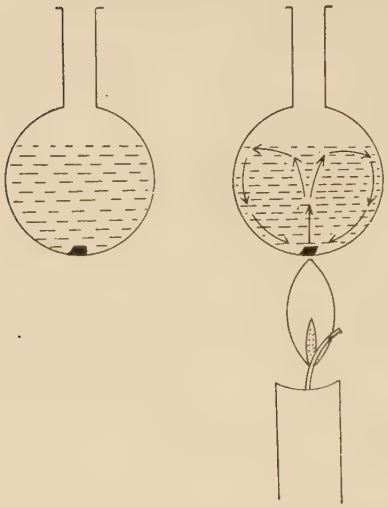


Fig. 41.—Convection currents.

(*b*) Apparatus.—Flask. Iron stand. Ring support. Source of heat.

Materials.—Some water, Crystals of potassium permanganate.

Procedure.—Arrange the apparatus as shown in Fig. 41. Fill the flask one-half full of water. Drop one large crystal of potassium permanganate so that it will fall at or near the center of the bottom of the flask as shown in the illustration.

Observations.—While applying a gentle heat to the bottom of the flask observe the crystal. Do you see streams of colored liquid? Observe carefully the path that they take through the liquid. Continue the heating and observe the path taken by the heated liquid. The water immediately above the flame receives the most of the heat. In the last chapter we learned that heat causes liquids to expand and occupy more space. Since the heated and expanded portions rise to the top, they must be lighter than the cold and unexpanded parts which sink to the bottom. This movement of the warm portions of the liquid to the top and of the cold portions to the bottom always takes place when we apply heat to the bottom portions of a liquid. The streams of warm liquid flowing up through the colder portions and the streams of cold liquid flowing down toward the flame are called *convection currents*. These convection currents carry the heat to all parts of the liquid. This method of carrying or transferring the heat to all parts of the liquid is called *convection*. When we want to warm a teakettle of water is there a reason for placing it over the fire rather than in any other position? Explain.

Gases

Apparatus.—Drinking glass. Lamp chimney or cardboard cylinder.
Materials.—Candle. Matches. Small piece of cardboard.
Procedure.—(*a*) Light and set the candle upright on a piece of cardboard. Allow the candle to burn up well. Invert the drinking glass and

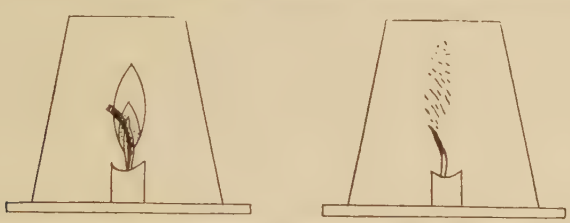


Fig. 42.—In the absence of convection currents no fresh supplies of air reach the candle.

set it over the burning candle as shown in Fig. 42. What happens? Explain.

(*b*) Light the candle and set the lamp chimney or cardboard cylinder down over the candle as in Fig. 43. What happens? Explain.

(*c*) Raise the lamp chimney one-half an inch from the cardboard as

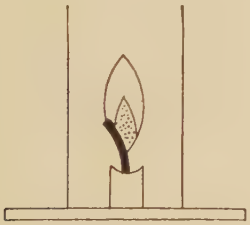


Fig. 43.—Is there a possibility of some fresh air reaching the candle?

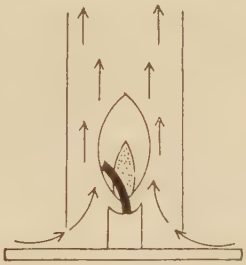


Fig. 44.—Are these conditions ideal for the production of convection currents?

shown in Fig. 44. Does the candle burn better? Why? Bring a lighted match to the open space below the chimney. Which way does the flame move? Why? Hold your hand over the top of the chimney. Do you feel air coming up and out of the chimney? Is it hot or cold? Is cold fresh air constantly entering at the bottom, and hot stale air rising up through the chimney and escaping at the top? This flow of air up the chimney is due to the fact that a volume of hot air is lighter than an equal volume of cold air. Consequently the warm light air is being constantly driven upward and out by the cold heavy air that enters at the bottom. When such streams of air result from the heating effects of some hot body or

flame, they are called *convection currents*. This method of carrying or transferring heat from one place to another is called *convection*. Make a study of a kerosene lamp or a gas lamp and see if you can find where the cold fresh air enters and where the heated and expanded air escapes. Explain why the gases and smoke from the fire in a stove or furnace rise and escape by way of the chimney. Why is the hot air at the top of the room? In a closed room open a window an inch or so at the top and at the bottom. Bring a candle flame near each of the openings. Which way does the flame point in each case? Explain why the candle flame behaves as it does in each case. If a wind is blowing against the window you will not get the desired results. Why? How do you regulate the flow of convection currents that take place in stoves and furnaces?

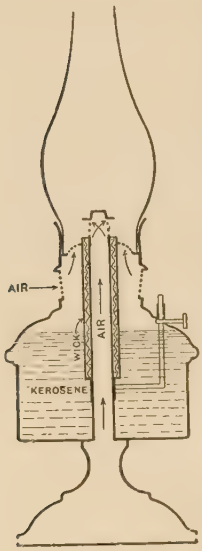


FIG. 45.—Make drawings in cross-section when attempting to set forth the internal arrangement of parts. The cross-section drawing of a lamp shows all the working parts and their relationship.

Using Knowledge Gained from Experiments.—Having learned from the foregoing experiments the methods and conditions of heat transfer, we are able to account for the particular construction of many of our household articles. A common teakettle may be made of many different metals; in fact, we find them upon the market made of copper, aluminum, iron, tin plate, enameled iron, and combinations of these metals. The question that arises in our minds is which of these materials we shall select for our teakettle. Shall we select the one made of copper, of iron, or of aluminum? What is to determine our selection? A teakettle is indispensable, and it is more used than any other utensil in our kitchens. It is used daily and many times daily for the purpose of heating water. Should the materials of which it is made be good conductors or poor conductors of heat? We know by actual experience gained from the above experiments that copper is a better conductor of heat than iron. Is it cheaper to operate a copper teakettle or an iron teakettle? The iron teakettle may be considerably cheaper to purchase, but the cost of the fuel and the loss in time make it more expensive than the purchase

and operation of one made of copper. Are we then to make use of the facts that we draw from experiments and experience, or are we to ignore such information?

Using Knowledge Gained from Books.—Shall we buy an aluminum teakettle? Since we did not use an aluminum wire along with the copper and iron wires, the above experiments did not give any information on the conductivity of aluminum. Is aluminum a better or a poorer conductor of heat than copper or iron? We shall find questions like this answered for us in texts on physics, in dictionaries, and in encyclopedias. Here the answer is usually found in the form of a table. We should learn how to read these tables and to obtain from them the information that we desire.

TABLE OF RELATIVE HEAT CONDUCTIVITIES

Silver	100.0	German silver	8.4	Pine, with grain	0.03
Copper	74.0	Mercury	1.7	Pine, across grain	0.01
Aluminum	35.0	Granite	0.53	Felt	0.008
Brass	27.0	Limestone	0.52	Air	0.005
Zinc	26.0	Ice	0.5		
Iron	15.0	Glass	0.2		
Tin	14.7	Water	0.124		

(*Smithsonian Physical Tables.*)

In the above table silver is the best conductor of heat; it is nearly four times better than zinc and seven times better than tin or iron. Aluminum is more than two times better than iron or tin. From this information we find that a copper teakettle is best, with aluminum second and iron third. However, in the past few years the price of aluminum utensils has been greatly reduced, and since aluminum ware is not easily tarnished and retains its white metallic luster under unusual conditions, it has come into general favor, and rarely do we see copper utensils for sale or in use in our present-day kitchens.

Aluminum Replaces Iron.—If you go into the kitchen and examine the frying pans, bread pans, kettles, and other cooking utensils, you will find many of them made of iron; enamel ware, which is iron covered with enamel; and tin plate, which is iron plated with tin. Iron is the most plentiful and the most durable metal that we have, and consequently it is the most used in the manufacture of our cooking utensils regardless of the

fact that it is a poorer conductor of heat than either copper or aluminum. However, aluminum is now being used in the manufacture of frying pans, kettles, and all similar articles, and in time will greatly replace those made of iron. Aluminum is a softer metal than iron, and is therefore more easily damaged when misused or mistreated; but since it is a better conductor of heat, has a pleasing white metallic luster, and is only one-third as heavy as iron, the housewife prefers aluminum articles to those of iron.

Nonconductors and Their Uses.—In our home life and daily needs we find that we require the service of nonconductors of heat as urgently as those of conductors. We must have wooden handles on our teakettles, curling irons, and stirring ladles, and wooden knobs on the lids and covers that fit our frying pans and kettles. Otherwise when hot these articles would be difficult and unpleasant to handle, for the heat that is in them would immediately pass off by the process of conduction into our fingers and thus burn them. When we wish to place hot dishes of heated foods upon the dining table, we place them upon pads of asbestos or cork. The refrigerator and fireless cooker must be constructed of the best possible nonconductors. The refrigerator must prevent the heat from entering, while the fireless cooker must prevent the heat from escaping. In order to accomplish these results the builder of refrigerators or fireless cookers must select the best nonconductors of heat and arrange them to the best advantage.

We found that liquids and gases are very poor conductors of heat, and that a body of water or air could not be heated unless the heat was applied in such manner as to cause convection currents. If these convection currents are prevented, the heating effects are also prevented. Consequently we make use of this when we build ice houses and cold storage plants for the storage of ice and perishable foods during the summer months. The ice house or cold storage is constructed with a layer of coarse sawdust between the double walls. The air that is between the particles of sawdust is unable to circulate and produce convection currents, and it is therefore called dead air, which serves as an excellent nonconductor of heat.

Clothing Materials as Conductors and Nonconductors of Heat.—Many materials, such as leather, felt, woolen cloth, and fur owe their property of nonconductivity mainly to the fact that they are porous—that is, there are numerous little air spaces between the fibers of which they are composed. The air that fills these minute spaces is one of the poorest conductors that we have and hinders the transfer of heat through these substances. Among the materials used for dress, fur, feathers, felt, and woolens are the poorest of conductors, while linen and silk are the best. Consequently furs, felts, and woolens are used as articles of clothing in cold climates and during the winter months in temperate zones, while linen and silk are worn in tropical climates and during the summer seasons.

However, when we go upon the market we find articles for summer or winter wear largely made of cotton materials. The manufacturer of cotton goods finds that he can closely imitate woolen, linen, and silken materials by varying his manufacturing processes while working up his cotton fabrics. He is able to manufacture a heavy or medium porous fabric that is a fair nonconductor of heat, and hence we find blankets and clothing materials for winter wear made of this cheaper substance. Since cotton fiber is thin and fine, it can be made up into thin fabrics that are quite serviceable for wear in hot climates and summer seasons. In recent years the cotton manufacturer has brought out a grade of mercerized cotton that can be finished to resemble so closely fabrics made either of silk or linen that we find the buying public readily accepting it as a substitute for these better materials.

The science of clothing is then to prevent the heat from escaping too rapidly from the surface of the body during cold and severe weather, and to allow it to escape in hot climates and during the hot months of summer. Our furs and woolens supply no heat; they simply act as nonconductors that prevent the escape of the heat that is being constantly liberated from our bodies. Linen and silk clothing, being good conductors, allow the heat to pass through and away from our bodies and consequently are worn largely during warm seasons and in hot climates.

Radiation.—When we walk around a hot stove or a bonfire, we find that the heat is thrown out in all directions. The heat seems to shoot out directly towards us, and wherever it strikes us we experience the presence of heat. When heat is emitted or thrown off by hot bodies, the heat is said to be radiated. Such heat is called *radiant heat.* Standing out of doors in the presence of the sun, we are instantly aware of its radiant heat. However, if we place a screen between us and the sun, the sensation of warmth ceases to be felt. On the other hand, if we sit behind a window exposed to the sun, we find that the radiant heat passes directly through the glass to us with very little loss, and wherever these rays of radiant heat strike the objects in the room, heating effects are the result. Substances like glass that allow radiant heat from the sun to pass through them without greatly heating them are said to be *transparent to heat.* Materials like paper, cloth, cardboard, and wood do not allow the radiant heat to pass them, but on the other hand they absorb the radiant heat and thus become heated. Such substances are said to be *opaque to heat.*

The earth's atmosphere is exceedingly transparent to the radiant heat from the sun, for, as we well know, the heat from the sun radiates daily through our great ocean of air with very slight heating effects. However, when this radiant heat strikes the opaque earth it is largely absorbed, producing heating effects that are considerable. The heated earth, being in contact with the lower layers of the atmosphere, warms them and thus gives rise to large convection currents of warm and cold winds of varying intensity.

Some materials absorb radiant heat better than others. Black materials absorb heat more readily than white. The reason for this is that white bodies instead of absorbing all of the radiant heat reflect part of it. Furthermore, bodies having rough surfaces absorb more heat than bodies that have polished surfaces. Indeed, bodies may have such highly polished surfaces that they are able to reflect most of the radiant heat that strikes upon them. However, bodies that are good absorbers of radiant heat are also good radiators of heat, while bodies that are poor absorbers are good reflectors but poor radiators of heat. This

can be nicely and easily shown by taking two cans of the same size, one covered with lampblack and the other highly polished, filling them with like amounts of hot water, and setting them aside with thermometers in them. It will be found that the black can cools off more rapidly than the polished one, thus proving that black unpolished surfaces are better radiators than polished surfaces. If we repeat the experiment with cold water and expose the cans to a source of heat, we will find that the water in the black can warms more readily than that in the polished can. Hence the darker an object is, the more it absorbs heat. Consequently light colored and white fabrics are more desirable for summer wear than dark materials. A radiator gives off more heat by radiation when it is painted black or bronze than when it is painted a light color. An aluminum teakettle will not cool off so rapidly as a black kettle, because it radiates less quickly. In conclusion it may be said that good absorbers of radiant heat are good radiators, and poor absorbers of radiant heat are poor radiators.

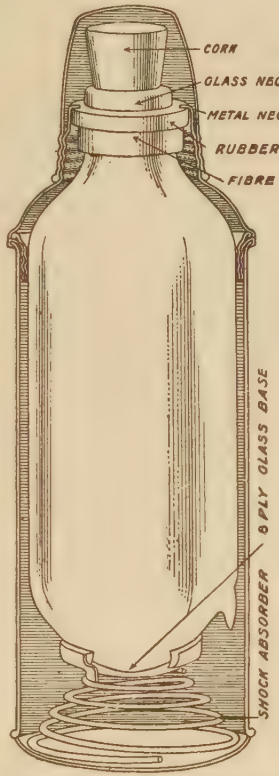


FIG. 46.—Sectional view of thermos bottle. (*From Tower, Smith, Turton, and Cope's Physics.*)

Projects

1. To determine which of the following materials is the more suitable for winter clothing, serge or gingham.

Suggestions.—Select two similar cans. Make holes in covers. Fit corks with thermometers, so that bulbs are in the center of cans. Completely cover with one layer of cloth. Fill with warm water and record temperature every thirty minutes.

2. To determine whether a black can or a polished can should be chosen for keeping liquids warm.

3. To determine whether a black can or a polished can should be selected for keeping ice water.

4. To study the construction of a thermos bottle in order to explain why it is possible to keep hot liquids hot, or cold liquids cold, when placed within them.

5. To make a study of two different brands or makes of thermos bottles in order to discover which gives the better service.

Suggestions.—Select corks to fit. Pass thermometers through corks. Record temperatures of cooling liquids every hour.

FIG. 47.—Cross-section of the vacuum flask in a thermos bottle. (*From Tower, Smith, Turton, and Cope's Physics.*)

6. To make a box receptacle for the reception of early morning delivery of bottled milk. Such a box is to keep the milk cool in the summer and from freezing and breaking the bottle in winter.

7. To repair or replace with suitable materials the holders, knobs, or handles that are broken or lost from kettles, covers, curling irons, soldering irons in and about the home.

8. To study the construction of a fireless cooker and to account for the materials used in its make-up.

9. To study the construction of an ice cream freezer and to account for such a construction.

10. (*a*) To study the construction and arrangement of the compartments in the home ice box.

(*b*) To record the temperature of the various compartments of the home ice box and to compare the record with those reported from other homes.

11. To study the hot water system in the home and to make drawings that set forth the principles of operation.

CHAPTER VI

FUELS, FLAMES, BURNERS, AND COOKING DEVICES

Object.—1. To make a study of the various kinds of fuels and the conditions under which they are best put to use.

2. To learn the conditions under which luminous and non-luminous flames are produced and the uses of each.

Introduction.—One of the largest business enterprises of today is the furnishing of fuels to the homes and factories. Without fuels to feed our fires there would be little or no comfort as we know it in our present form of civilization. Our homes are made comfortable because of great and easily accessible supplies of wood, coal, and oils; our industries in every form and manner depend upon a constant supply of fuel. Flames were largely used to light our homes and streets, but this use of flames is fast giving way to the safer and more convenient form of electric lighting. However, flames are still used in the homes for heating and cooking, and in the industries in various ways to bring about the manufacture of the millions of articles demanded in our every-day commercial world. A few years ago the people were little concerned with the problems arising from shortage of fuels. However, today this problem is before us and demands consideration in order to bring about its solution. Conservation of resources is possible only when all sources of waste are cut off. A knowledge of fuels and a more intelligent understanding of the appliances in which they are burned or used will aid greatly and make possible a reasonable conservation of our national resources of fuel supply.

THE CANDLE FLAME

Object.—To study a burning candle in order to learn the relation that the materials of the candle bear to the flames.

MATERIALS.—Candle, matches, drinking glass or wide mouth bottle, piece of iron wire, six inches of glass tubing.

PROCEDURE AND OBSERVATIONS.—1. Light the candle and allow it to burn for four or five minutes in a quiet place. Has a cup formed on the top of the candle? What is the liquid in the cup? Whence came this liquid? Does the candle grow shorter? Does the wick stand in the center of the melted paraffin? What is the purpose of the wick? Hold a towel or piece of cloth so that one end hangs in a basin of water and observe whether the water "climbs" up the towel. Hold a lump of sugar or salt so that one end of it dips in a large drop of ink. What happens? Repeat with a piece of blotting paper. *The force that causes liquids to travel up between the fibers or particles of any material is called capillary attraction.* Does the liquid in the cup pass up the wick to the flame? Bend the wire into a U-shape and pinch those portions of the wick within the flame and withdraw the wire immediately. Are the ends of the wire wet with liquid paraffin? Blow out the flame and examine the wick. Is it wet in all portions? Is the wick soaked with melted paraffin all the time that the candle burns?

2. Relight the candle and allow it to burn up well. With a quick puff blow it out. Observe the white vapors arising from the hot wick. Do the vapors of paraffin continue to pass off after the wick has cooled? Relight and allow the candle to burn up well. Have a lighted match ready and then blow out the candle. Bring the flame of a match into the stream of paraffin vapors. What happens? Repeat several times in order to find the greatest distance at which you can get the candle to relight. Hold a glass tube so that one end stands in the dark center of the flame. Do the white vapors of paraffin escape through the tube? If so bring a match to the end of the tube. Do the vapors burn?

3. When the candle is burning we have three states of paraffin,—solid, liquid, and vapor. Where is each located? Which one is it that burns? Before you can burn paraffin what must take place?

4. Paraffin is a compound of hydrogen and carbon, and when the vapors of paraffin reach the hot portions of the flame the compound is broken down into the elements of hydrogen and carbon. Proceed as follows to prove the fact. Hold an inverted drinking glass or wide mouth bottle above the flame. Observe the formation of a layer of water vapor on the inner surface of the glass. What element combines with oxygen to form water? Where did the oxygen come from? Hold the cold glass so that the flame touches the outside wall and observe what takes place. What is the black material called? Where did it come from?

5. Stick one end of the wire into the lighted candle and lower it into a bottle. Cover the bottle and allow the candle to burn out. Remove the candle and add some lime water. Shake. Explain results. Is all the carbon burned to carbon dioxide or is some of the carbon set free? If you are in doubt repeat part four above.

6. Is the process of combustion complete or incomplete in a candle flame? Substances that furnish a supply of combustible material serve well as fuels. Do you consider paraffin a good fuel substance? Explain.

FLASHING AND BURNING POINTS

Object.—To observe the flashing and burning points of such fuel substances as paraffin, tallow, and like combustibles.

APPARATUS.—An iron spoon and a source of heat.

MATERIALS.—Paraffin, matches or wooden splinters. Some sand or flour.

PROCEDURE AND OBSERVATION.—Place a piece of paraffin in the spoon and slowly heat until vapors appear at the surface. Test the vapors with the flame of a match or burning splinter to see if they will burn and produce a momentary flash over the surface of the hot paraffin. If they do, the paraffin has reached its *flashing point.* Allow the spoon and contents to cool and repeat the test until momentary flashings cease on testing with a flame. Reheat carefully until the *flashing point* is again reached. Continue heating and testing until the supply of vapors becomes more and more dense and sufficient to cause a continuous flame. When the supply of vapors is sufficient to allow continuous burning, the paraffin has reached its *burning point.* To extinguish the flame fill the spoon with sand, flour, or earth. Write a statement defining *flashing point; burning point.*

The experiment may be repeated with very small amounts of lard, tallow, and olive oil. Kerosene should be used only in the presence of the teacher or parent and no more than a teaspoonful of the oil should be placed in the large spoon. Because of their very low flashing points, gasoline and similar fuels must be left for experienced operators.

LUMINOUS AND NONLUMINOUS FLAMES AND BUNSEN BURNERS

Object.—To learn how to operate a Bunsen burner, and the conditions under which it produces luminous and nonluminous flames.

APPARATUS.—Bunsen burner connected to a supply of natural or artificial gas. A wide mouth bottle or drinking glass.

MATERIALS.—Lime water and matches.

PROCEDURE AND OBSERVATIONS.—Take the Bunsen burner apart and examine each detail. Put the burner together and note the relationship of the various parts.

1. Adjust the brass ring (damper) at the base of the burner so that the holes are covered. Turn on and light the gas by bringing a lighted match over the top of the burner. Adjust the supply of gas until the flame is two or three inches high. What color is the flame? Does it give off considerable light? Are carbon particles (smoke) being given off by the flame? Hold a cold glass for a second or two in the flame. Does moisture collect similar to that seen when studying the candle? Where did the elements hydrogen and carbon come from?

2. Turn the brass ring (damper) at the base of the burner until the flame is entirely changed in appearance. What is entering the holes and

mixing with the gas as it rises up through the tube of the burner? Does the flame have a smoky appearance? Close the holes with your thumb and finger and note the effect on the flame. Remove your thumb and finger from the burner and pass a cold bottle through the flame. Do particles of carbon (soot) black the surface of the bottle? Does the extra supply of air entering the holes supply more or less oxygen to the flame? Does this extra supply of oxygen aid in burning the carbon? When does the flame give more light, when the holes are closed, or when the holes are open? Which gives off the more soot (fine particles of carbon)? Which one is more like the candle flame in color and light giving? Does the candle give off free particles of carbon (soot)? Do the red-hot particles of carbon in the flame cause the lighting effect, and thus cause the flame

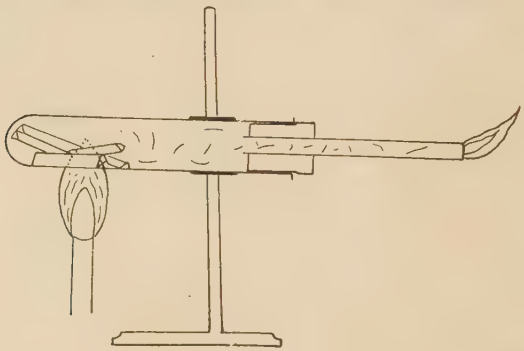


FIG. 48.—Arrangement of apparatus for the destructive distillation of coal and wood.

to be luminous? When these particles of carbon are mixed with oxygen they burn and form carbon dioxide. If all the particles are burned there are no red hot particles to give off light. Does this explain why the flame is nonluminous when the holes are open? If more carbon is burned when the holes are open than when they are closed which flame is the hotter? Which flame would you rather read by? Which would you use to cook with? Which would blacken the pots and kettles? Which would leave them clean? Of what service are luminous flames? Nonluminous flames? Of what use is the Bunsen burner?

WOOD AND COAL: DESTRUCTIVE DISTILLATION

Object.—To make a study of wood and coal and to observe the changes that they undergo and the products that they give off when heated.

APPARATUS.—Hard glass tube fitted with a cork. 6-inch glass tube, round file, rubber tubing, iron stand, and burette clamp.

MATERIALS.—Pine chips or splinters. Powdered soft coal.

PROCEDURE.—Place a few pieces of pine in the test tube and then set up the apparatus as shown in Fig. 48, being sure to have the test tube slightly

slanted as indicated. Apply heat slowly at first and then more and more strongly to the pieces of wood.

OBSERVATIONS.—1. Observe closely what takes place. Apply a lighted match or splinter every few seconds to the vapors issuing from the tube. The first portion of the vapors may be largely made up of steam. Where did the moisture come from that produced the steam? Is water a good or a poor substance to have in a fuel? Explain.

The second portion of vapors coming off is rich in vapors of wood alcohol, acetic acid, and compounds composed of hydrogen and carbon, commonly called hydrocarbons. Do they burn? Heat until the vapors cease to burn at the mouth of the glass tube. Cool the test tube by fanning or setting it in a draft of cold air. Remove and examine the solid substance remaining in the tube. What is it? How is charcoal made on a commercial scale? Is charcoal a good fuel?

2. Repeat the experiment with some powdered soft coal. Does soft coal give off a greater or less quantity of vapors of hydrocarbons? Examine the solid substance left in the tube. What is it? How is coke made on a commercial scale? Do gas companies usually have it for sale? Why? Is coke a good fuel? Does coal or coke cost more per ton in your town? When coal is burned in a furnace, which burns first, the gases and vapors that it contains or the coke? Which burns the more rapidly? More slowly? Place the piece of coke and charcoal on a wire gauze and heat them strongly and see if you can make them burn with a flame. When should the draft of a heating device be closed and the check draft be opened, before or after the gases and vapors have burned off? Explain.

The First Fuels Used by Man.—Wood, dried grasses, and occasionally some animal fats were the only fuels used by ancient and medieval peoples. Savage and ancient man had no perfected device or appliance in which to burn his fuels. He simply built a campfire on the surface of the ground and regulated it by varying the amount of fuel. When a fire was built in a tent or a cave, the smoke was allowed to escape from the hole in top of the tent or from the top of the mouth of the cave. Even in the homes of the Romans the heat and smoke entered the living rooms from the fire rooms in the cellars. Such a method would seem exceedingly unpleasant to us, especially if fresh wood were placed on the fire, causing disagreeable vapors and much smoke to enter the living apartments. Smokeless and odorless fuels like charcoal would have been more agreeable in the Roman arrangement, but such a use of charcoal does not appear to have been made.

The Chimney and the Fire Place.—When we study the history of man, we find that it took him a surprisingly long time to invent and bring into use some of our simplest and most necessary appliances. The invention of a chimney does not appear to have taken place until the time of the Norman Conquest of England in 1066. At this time the Britons built their fires on the floors and allowed the smoke to escape through a hole in the roof. The warriors who were fighting from the house tops were much hindered and distressed by the escaping smoke. Then it seems that they moved the fire from the center of the room near to a side wall in which they had made a hole. Stones were built up on either side of the fire so as to conduct the smoke more readily to its new exit. In time this arrangement was improved, and finally developed into the open fire place with its chimney. This was, indeed, a great invention, for it made possible a greater degree of human comfort and security. For the next seven hundred years the fireplace was the only means of providing warmth and heat for cooking and preparing foods.

Early Stoves.—While the fireplace with its chimney was a great convenience over the ancient and medieval methods of house warming, people found it very unsatisfactory and longed for improvements. Nine-tenths or more of the heat passed up the chimney without warming the room and its occupants. While the great drafts of hot air were escaping up the chimney, blasts of cold air entered at every crack and swept across the room to the mouth of the fireplace. The occupants of such rooms would be chilled on one side and uncomfortably heated on the other.

In 1742 Benjamin Franklin invented his iron stove. These stoves were placed in the fireplace in such a way as to allow the smoke to pass up the chimney. The air in the rooms, coming in contact with the sides of the stove, became heated, and thus circulating around the room warmed it more efficiently than did the fire in the fireplace. While the old fireplace consumed large quantities of wood with little heating effect, Franklin states that his stove warmed his room twice as much with one-fourth the wood that was formerly required. Franklin stoves remained in use in this country and in Europe for nearly

a century, few or no improvements being made in the original design.

Better Stoves; Coal and Iron.—In an earlier lesson we burned iron in a jar of oxygen and thus brought about a compound of iron oxide commonly known as iron rust. Large deposits of iron oxide, or iron ore, are found in nearly every country in the world, and man has known for centuries how to get iron out of iron ore. A very early method was to pile iron ore and charcoal together in a very hot fire, and then when the fire had died out, lumps of iron were found among the embers. These precious pieces of metallic iron were shaped into spear heads and knives and parts of other useful articles. The Romans were unable to make much improvement on this process of iron making, except that they used a goat skin bellows to force more air into the burning pile, and thus they were able to produce a more intense heat and therefore more iron. During the American Revolution the iron for Washington's cannon and muskets was made in forges or tall furnaces not unlike big stone chimneys. The fire was fed by a forced draft commonly produced by a water wheel which worked a large bellows. We must not think that because these earlier peoples found it difficult to make iron they could not make good iron. The fact is that their iron was as good as any made today and often much better. The principle of iron making has always been the same whether it was made in ancient Asia, Rome, or in the time of George Washington or Andrew Carnegie. A hot fire, feeding on a mixture of charcoal and iron ore, sets iron free in a metallic form.

As long as charcoal had to be used in the iron industry, the manufacture of iron was very much limited for two reasons. First, the iron industry had to move about, following the forests, to get a supply of charcoal. Secondly, as long as charcoal was used for the fire, the materials could not be piled up very high because the weight of iron ore would crush the charcoal and smother the fire. For these reasons it is very fortunate that man learned to make coke from coal. Coke is hard, and layers of coke and iron ore can be piled to a great height and still allow the air to be forced through to feed the fire. Again, coal is abundant in many places, and thus the iron

industries were able to settle down and to develop into large centers that produce large quantities of iron from huge blast furnaces at surprisingly low costs per pound. While it cost the Romans about a dollar in our money to make a pound of iron, it costs us only a cent a pound and sometimes even less.

In and about the centers where the manufacturers of iron had settled, other industries that manufactured the iron into

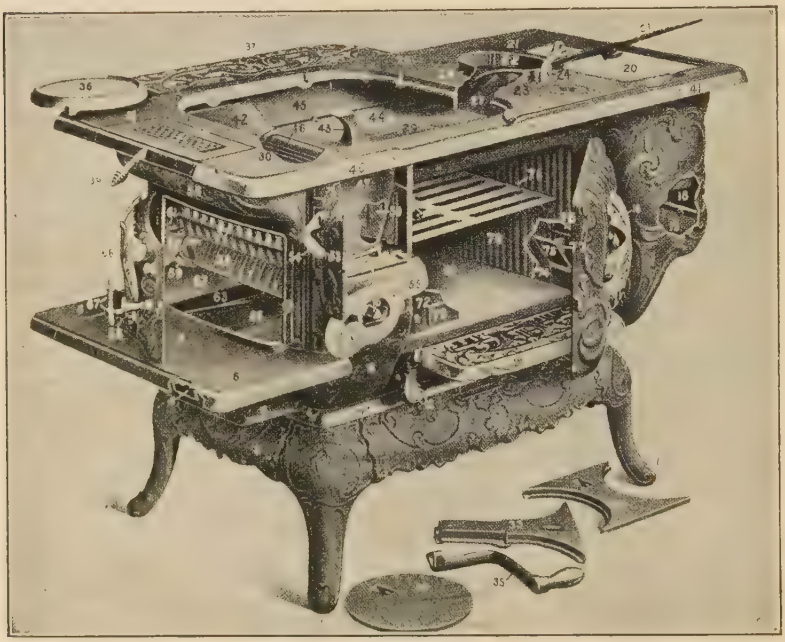


FIG. 49.—A cook stove with a hot water reservoir. Direct damper draft (27). Damper handle (24). Reservoir damper (75). Flues in bottom of oven (72 and 73). Small door that permits the cleaning of flues (5).

useful articles came quickly into existence. These factories turned the iron of the blast furnace into axes, hammers, saws, knives, chains, nails, wire, rods, boat fittings, agricultural machinery, and a million other articles so useful in everyday life. With the development of the iron industry, improvements in articles already in use and the invention of new articles came with such surprising rapidity that the nineteenth century has been boasted the greatest century of human progress.

In a short time the American cook stove and better forms of warming stoves with their cast (later sheet) iron chimneys had completely replaced the old time open fire place and Franklin stove. The stoves were provided with grates suitable for the burning of coal as well as wood. The present form of our common cook stove is a very simple arrangement. An oven with double walls is placed immediately behind the fire pot. An oven damper is so placed, Fig. 49, that, when properly set, it directs the hot gases between the walls of the oven before they are permitted to pass to the chimney. This distribution of the heat results in the oven's being more or less uniformly heated, thus producing conditions that are excellent for baking and cooking. Near the bottom of the cook stove there is a small door by means of which the space between the walls or the flues of the oven may be cleaned of soot and finely divided ashes deposited there by the circulating gases. Otherwise the efficiency of the cook stove is greatly decreased if the flues are allowed to remain partially clogged with these deposits. For many years in a majority of American homes the cook stove served not only as a cooking device but as a heating device.

Classification of Fuels.—Since the invention of the common cook stove many other devices have come into use. The form of these devices depends largely upon the nature of the fuel that is burned in them. The fuels which are used in household operations are of three groups: (1) Solid fuels, such as hard or soft coal, coke, wood, charcoal, lignite, and peat; (2) liquid fuels, such as kerosene or "coal oil," gasoline, crude oil, fuel oil, and alcohol; (3) gaseous fuels, such as gasoline vapors, natural gas, and acetylene. Advantages and disadvantages of the various fuels may be summarized as follows:

ADVANTAGES AND DISADVANTAGES OF VARIOUS FUELS AND OF ELECTRICITY*

Fuel	Advantages	Disadvantages
Wood	(*a*) Cleanliness, (*b*) cheerful fire, (*c*) quick increase of heat, (*d*) cheapness in some localities.	(*a*) Low fuel value, (*b*) large storage space necessary, (*c*) labor in preparation, (*d*) scarcity, (*e*) failure to hold fire long, (*f*) unsteady heat.
Anthracite	(*a*) Cleanliness, (*b*) easy control of fire, (*c*) heat obtained more easily than is the case with other coals, (*d*) steady heat.	(*a*) High price, (*b*) difficulty of obtaining, (*c*) slower response to change of drafts.
Bituminous coal	(*a*) Low price, (*b*) availability, (*c*) high heat value (in the best grades), (*d*) low percentage of inert matter (in the best grades).	(*a*) Dirt, (*b*) smoke produced, (*c*) more attention to fire and furnace necessary than with anthracite.
Subbituminous coal and lignite.	(*a*) Relatively low price, (*b*) availability (in some regions), (*c*) response quick to opening of drafts.	(*a*) Slaking and deterioration on exposure to air, (*b*) taking fire spontaneously in piles, (*c*) generally low heat value, (*d*) difficulty of realizing heat in fuel, (*e*) failure of fires to keep well, (*f*) gases generated over fire pot sometimes burning in smoke pipe, causing excessive heat.
Peat	(*a*) In general, the same as for wood.	(*a*) Low heat value, (*b*) bulkiness.
Coke	(*a*) Cleanliness, (*b*) quick response to opening of drafts, (*c*) fairly high heat value.	(*a*) Bulkiness, (*b*) tendency of fire to go out if not properly handled, (*c*) rather frequent attention to fire required unless fire pot is deep.
Oil	(*a*) High heat value, (*b*) immediate increase of heat, (*c*) cleanliness, (*d*) small storage space necessary.	(*a*) High price, (*b*) difficulty of safe storage.
Gas	(*a*) Ease of control, (*b*) cleanliness, (*c*) convenience, (*d*) immediate increase of heat.	(*a*) High price in many places.
Electricity	(*a*) Every advantage.	(*a*) High price.

* Department of Interior Technical Paper 97.

All of these common fuels owe their fuel value to two elements, carbon and hydrogen, which occur in the compounds of the fuel. Sometimes there are other elements and compounds which do not add to the heat producing qualities of the fuels. These nonacting elements or compounds go to make up the wastes which pass off as gases or remain in the form commonly known as ashes. All solid fuels contain, more or less, amounts of useless materials. Low grades of coal contain quantities of moisture, slate, iron, or sulphur, or compounds of iron and sulphur, all of which lower the heating values of the fuel. Poor grades of gas contain carbon dioxide, sulphur dioxide, ammonia, or nitrogen, none of which contributes to the heating effects of the flame. Such impurities in fuels lower their usefulness.

Products of Combustion.—Compounds made up of hydrogen and carbon are called hydrocarbons. Paraffin, kerosene, and gasoline are good examples of compounds made up entirely of hydrogen and carbon. When these compounds are heated they give off vapors—that is, they volatilize. In the presence of a flame these vapors break down into hydrogen and carbon. The hydrogen gas is extremely combustible and so unites with the oxygen of the air that comes against the flame. Hydrogen and oxygen form only one product, which is water vapor. Cool objects held in flames where hydrogen is burning, always condense the water vapor and become covered with a film of moisture. The carbon is not so combustible as the hydrogen, and so, if the supply of oxygen is short or not enough to supply each of the carbon particles (atoms), we may have three results. (1) We may have the carbon particle or atom completely burned to carbon dioxide—that is, one carbon atom combined with two atoms of oxygen. (2) We may have one carbon atom combined with only one atom of oxygen, thus forming carbon monoxide, which is a very poisonous gas. (3) We may have particles of carbon leaving the flame not burned at all. Such particles form smoke and are deposited on the walls, curtains, and other articles as soot. Carbon monoxide is usually present in the exhaust from gasoline engines, and is sometimes given off in dangerous quantities; many cases of fatal asphyxia-

tion in garages have occurred because of failure to appreciate the danger of air so contaminated.

Flames.—Whenever carbon is burned alone—that is, in the form of charcoal or coke, it does not vaporize before burning, but burns simply as a solid. In this process the hot charcoal or coke is combining directly with the oxygen from the air, forming not a flame, but simply a glowing (incandescence) due to production of both heat and light. However, hydrogen and practically all of the hydrocarbons burn with a flame.

Soft coal is rich in various kinds of hydrocarbons, and so, when this variety of coal is laid on a fire, these hydrocarbons are vaporized as the coal becomes heated. The vapors spring forth from the cracks and crevices in the lump of heated coal and are immediately ignited on reaching the surface, forming flaming tongues of fire that are more or less luminous. When all of the hydrocarbons have been distilled out of the lumps of coal, the carbon or coke that remains burns with a glow. Burning woods of all varieties behave in a manner similar to coal. Hard pine is especially rich in hydrocarbons and for this reason was adaptable as a torch in primitive and ancient times.

Artificial and Natural Gas. The Gas Meter.—The use of coal and wood for cooking and many other household purposes has largely been displaced by the use of liquid and gaseous fuels. In certain large centers natural and artificial gas is conducted by pipe lines to nearly every home in the community. Large corporations which either collect the gas from wells, distill it from coal, or manufacture it from red hot coke and steam, sell the gas to the householder at a certain rate per 1000 cubic feet. The pipe line on entering the home passes to a gas meter and from there to the gas stove.

The chief thing about the gas stove is the modified form of the Bunsen burner that is employed for burning the gas. The Bunsen burner studied in the laboratory is simply an arrangement in which the gas is mixed with a proper quantity of oxygen before it reaches the flame. This form of the Bunsen burner is not serviceable in a gas stove, but the essentials and parts are exactly the same. As shown in Fig. 50, the burner lies in a horizontal position. The gas is forced through a small hole

and thus acquires a relatively high velocity. As the gas rushes into the burner an aspirating or sucking action is produced around the air holes of the burner and draws in the atmospheric air from the room. The result is a mixture of air and gas. When the damper or air shutter is properly adjusted to the gas supply, a noiseless and nonluminous flame is the result.

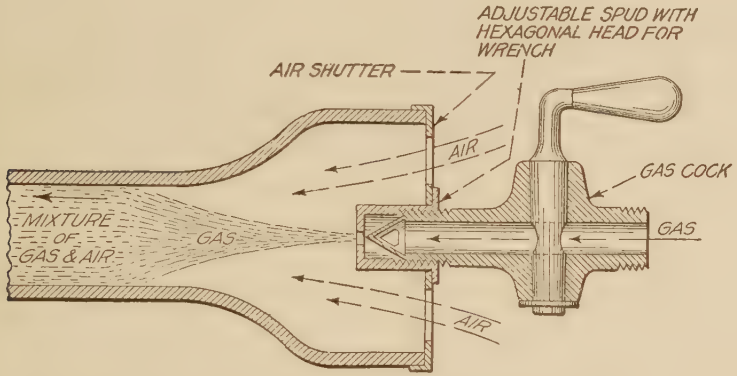


FIG. 50.—Diagram showing construction of gas mixer, with adjustable spud. (*From Technical Paper 257, Dept. of Interior*, 1920.)

Liquid Fuels.—In rural sections and country villages, kerosene and gasoline are used in appliances known as oil stoves. Devices of various sorts are employed by the various makers of stoves to transform the liquid fuel into vapors, which are then conducted to a gas burner. In recent years the oil burning stoves have been brought to a degree of perfection that makes them fairly safe and practicable. However, there is still the danger and inconvenience of handling dangerous fuels when using these appliances, and for this reason their use should be limited to those who are experienced and cautious from habit.

The Amount of Heat Obtainable from Fuels.—When any particular substance is used as a fuel, a definite amount of heat is released by combustion. This quantity of heat is known as the heating value of the fuel. The amount of heat required to heat one pound of water one degree Fahrenheit is commonly called the British thermal unit. If we heat two pounds of

water one degree, two British thermal units would be required. Ten pounds of water heated ten degrees would take up 100 British thermal units. The amount of heat produced is not by any means the same for the different fuels. One pound of dry soft or hard wood when burned will liberate 8000 Btu. (British thermal units), while a pound of soft or hard coal of average quality when burned will give up 13,000 Btu. One pound of charcoal produces twice as many heat units as a pound of wood, while gasoline produces 19,000 Btu. per pound. Gaseous fuels are measured and sold by the 1000 cubic feet. One cubic foot of natural gas when properly burned yields 1000 Btu., while the average manufactured gas produces only 600 Btu. per cubic foot.

COMPARISON OF FUELS

Material	Heating value	Assumed price	Gallons of water which could be heated from 32° to 212°F. for 1 cent
	Btu. per lb.		
Soft wood	8000	$5 per cord (1½ short tons)	32.0
Hard wood	8000	$5 per cord (2½ short tons)	53.3
Soft coal	13,000	$4 per short ton	43.0
Hard coal	13,000	$7 per short ton	25.0
Coke	12,000	$5 per short ton	32.0
Charcoal	16,000	$25 per short ton	8.5
Fuel oil	18,000	$1.25 per barrel (42 gallons)	30.0
Kerosene	18,000	$0.10 per gallon	8.3
Alcohol	12,000	$0.50 per gallon	1.0
Gasoline	19,000	$0.25 per gallon	3.5
Ice (to absorb heat)	160	$0.35 per 100 pounds	*a*.32
	Btu. per cu. ft.		
Natural gas	1000	$0.40 per 1000 cubic feet	17.0
Manufactured gas	600	$1 per 1000 cubic feet	4.2
	Btu. per kw. hr		
Electricity	3400	$0.10 per kilowatt-hour	0.23

[a] Water from 212°F. to 32°F., gallons for 1 cent.

NOTE.—Ice in melting absorbs 143 Btu. per pound, but the ice water thus formed also absorbs from 15 to 20 Btu. additional before it leaves the refrigerator, making a total of about 160 Btu.

Hard coal when burned gives out about 13,000 Btu. per pound, and if it costs $7 per ton the last column shows that 25 gallons of water can be heated from 32° to 212°F. by burning 1 cent's worth of coal, provided none of the heat is lost; or kerosene supplies 18,000 Btu. per pound, and 1 cent's worth of it at 10 cents per gallon would heat 8.3 gallons of water from 32° to 212°F. From *Circular No. 70, Department of Commerce.*

Projects

1. To study the construction and operating principles of a gas meter and to explain to the class by means of diagrams on wall charts the results of the investigation.

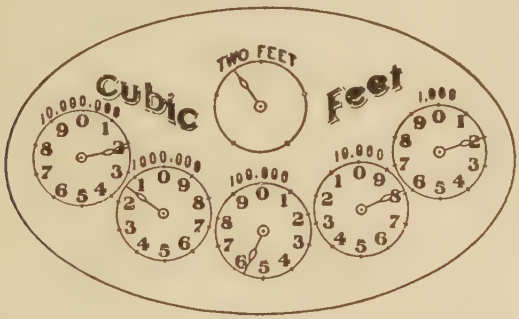


FIG. 51.

Figure 51 represents the dial of a Westinghouse Improved Fluid Positive Gas Meter. In reading, take the last figure the needle has passed, first on the circle

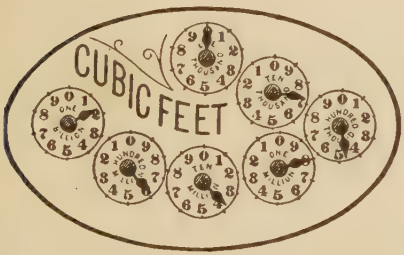


FIG. 52.

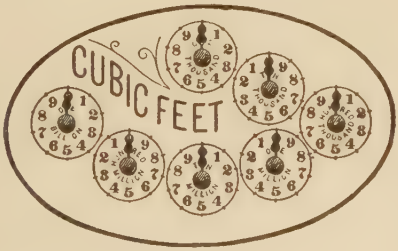


FIG. 53.

marked one thousand, then the next larger, and so on; the circle marked two feet is used for proving only.

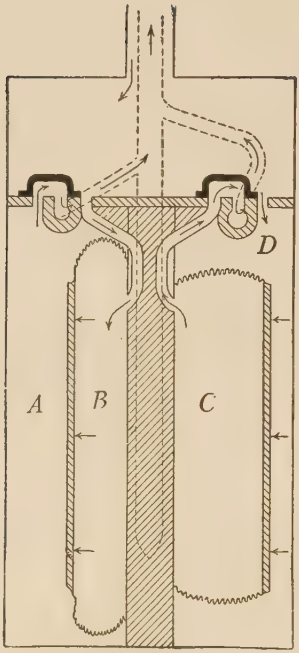


FIG. 54.—Cross-section of a gas meter showing its construction and action. (*From Tower, Smith, Turton, and Cope's Physics.*)

For example, the reading of dial in Fig. 51 is as follows:

On one thousand circle....	200 cu. ft.
On ten thousand circle....	8,000 cu. ft.
On hundred thousand circle.	50,000 cu. ft.
On one million circle.....	100,000 cu. ft.
On ten million circle.....	2,000,000 cu. ft.
Full reading of dial.....	2,158,200 cu. ft.

1. To find the full reading of dial in Fig. 52.

2. To make a study of the flames and burner positions shown in Fig. 55 in order to determine whether the gas range in the home permits the right or wrong use of the gas, and to make a report of the findings.

3. To write and illustrate with pictures from magazines or advertising literature a theme on "Natural Gas and Gas Wells."

4. To learn to read the gas meter in the home, to keep a daily record for a period of fourteen days, to make a graph of the readings in order to determine the day or days of the week in which the greatest consumption of gas occurs, and to determine the possibility of cutting down the monthly bill and conserving in the use of gas. Graph the number of cubic feet of gas against the days.

Number of cubic feet of gas	M	T	W	T	F	S	Su	M	T	W	T	F	S	Su
10														
9														
8														
7														
6														
5														
4														
3														
2														
1														

5. To locate on a large wall map the oil fields of North America, to present statistical figures showing the annual production and consumption of crude oil and refined products for the past ten years, and to show the need of conservation of natural resources.

6. To read and to make an oral report of "The Autobiography of a Piece of Coal," by Taylor.

7. To learn how coal gas is produced, and to demonstrate the process before the class.

8. To write and read a theme on "The Development of the Stove." (Read Burns' "Story of Great Inventions.")

9. To make a collection of the various kinds and grades of fuels and to display them in an attractive and educational manner in some conspicuous place in the school. The exhibit should be clearly labeled and might well be

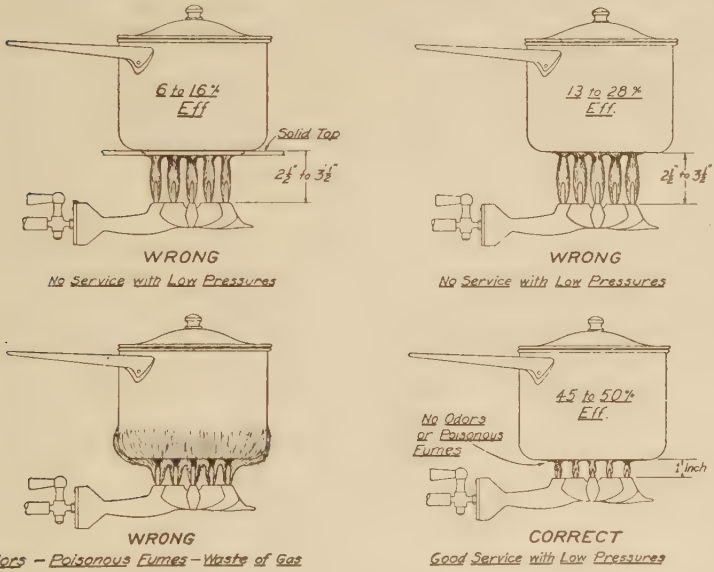


FIG. 55.—Right and wrong use of natural gas. U. S. Bureau of Standards, Washington, D. C. If the solid tops of stoves were removed and replaced by grids, the burners raised, and all domestic appliances operated correctly, $1,000,000 worth of natural gas would be saved daily.

accompanied with pictures illustrating the place from which the sample was taken. Figures of production and consumption are also educational when properly used.

10. To learn how crude oil is refined into the many products that we find upon the market, to obtain a set of lantern slides bearing upon the subject, and to show and explain them to the members of the class.

11. To learn how gasoline is graded and priced for the market, and to report the laws, rules, and regulations governing its sale and storage.

12. To make a study of a Welsbach burner and gas mantle and to set forth the need of a gas mantle in a formal demonstration. Go into detail concerning the construction of the burner and the mantle. Compare the burner with a Bunsen burner.

CHAPTER VII

HOW OUR HOMES AND PUBLIC BUILDINGS ARE HEATED

Object.—To study the construction and operation of the various heating devices that are employed in our homes and public buildings.

a. Stoves
b. Hot air furnace
c. Hot water heating systems
d. Steam heating systems

STOVES

Object.—To study the construction and operating principles of a common heating stove.

DIRECTIONS.—Make a careful study of the stove which is found in the home. Learn the names and uses of the various parts. Those who have no stoves in their homes may visit the hardware store where stoves are sold or make a study of the pictures and diagrams of stoves in a stove catalog. Make a diagram of the stove studied. Label all important parts. How is the fire controlled? What fuels are used? Are there various types of stoves? Name the leading types.

HOT AIR FURNACE

Object.—To study the construction and operating principles of a hot air furnace in a modern home.

DIRECTIONS.—Those students who have other heating systems in their homes should arrange to study and observe with neighboring classmates or friends whose homes are so provided.

Learn the names and uses of the various parts. Discover the location of the fire pot, the grate, and the ash pit. How do the ashes get into the ash pit? Is there a draft in the ash pit door or just above the door? When is this draft opened and when closed? Where does the air go that enters this draft? Is this draft of air necessary? Explain.

Where do the smoke and various gases that arise from the fire escape from the fire box? Where does the furnace pipe conduct the smoke and gases? Is there a check draft in the furnace pipe and what is its purpose? Locate the fuel door. Is there a draft in the fuel door and what is its purpose?

Locate the cold air pipe, and discover where it receives its supply of cold fresh air. What part of the furnace does the cold air enter and

why? Where does the hot air leave the furnace and why? How is the hot air distributed to the various rooms? Are there dampers in the hot air pipes and what is their purpose? Locate the hot air registers in the various rooms.

Make a cross section diagram of the hot air furnace and label the parts. Are there any disadvantages in this method of heating? Name them and compare them with the advantages of such a system. Is this system suitable for large or small buildings? Give reasons for your answer.

HOT WATER HEATING SYSTEM

Object.—To study the construction and operating principles of a hot water system of heating in a modern home.

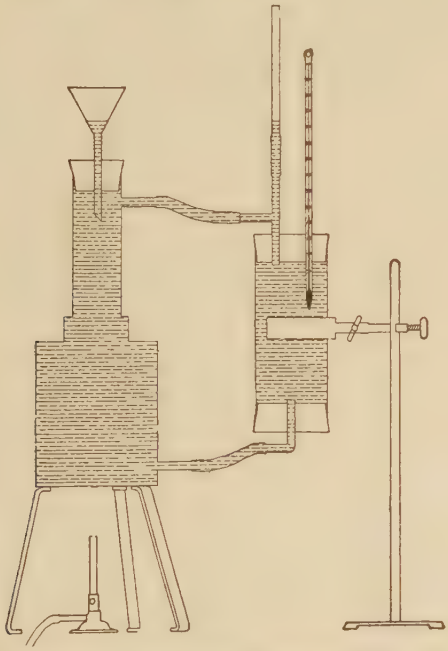


FIG. 56.—(*Practical Physics Manual by Ahrens, Harley, and Burns.*)

DIRECTIONS.—Proceed in the same manner as directed in the study of a hot air furnace. Those who have no opportunity of studying such a system in a home may construct and operate a model hot water system. Fig. 56 suggests how to construct a working model. The various parts of such a model hot water heating plant can be found in the Physics department and may be borrowed through your instructor.

Where does the hot water leave the heater? Where does it return? Locate the hot water radiators in the room. Where does the water enter the radiator? How does the heat get out of the radiator? Where does

the cold water leave the radiator? Is there an air vent on the side of the radiator and what is its purpose?

Locate the expansion tank in a hot water system. Is it a necessity? Give reasons.

Is the hot water system a good means of supplying heat? Does it make provision for a supply of fresh air along with the heat? How is the fresh air supplied?

Make a diagram of the hot water system and label the important parts. Place arrows in the diagram showing the direction of the flow of the hot and cold water.

STEAM HEATING. VAPORIZATION AND CONDENSATION

Object.—To learn how heat is carried by steam from one place to another.

Apparatus.—Flask fitted with a two hole rubber stopper, glass tubing and rubber connections, two thermometers, beakers, iron stand fitted with iron ring and burette clamps, wire gauze, and a source of heat.

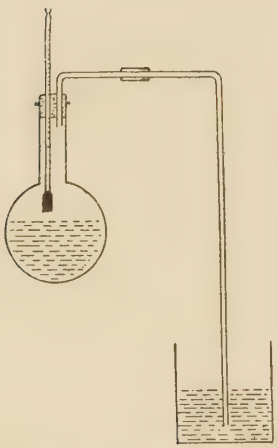


Fig. 57.—Arrangement of apparatus to show heating effects of steam.

Procedure.—Arrange the apparatus as shown in Fig. 57. Fill the flask and beaker about one-third full of water. Record the temperature, and carefully apply the heat to the wire gauze that supports the flask. Bring the water to the boiling point and then regulate the flame so as to keep the water boiling steadily, but not too strongly. Observe the thermometer readings from time to time. Is heat being carried from the flask to the water in the beaker? When the temperature of the water in the beaker has been raised thirty or forty degrees, move the beaker to one side. Withdraw the heat from the flask.

When water is changed to steam the process is called *vaporization*. When steam is changed to water the process is called *condensation*. In which process was heat taken up? In which process was heat given up? Is this a good method for transferring heat from one place to another?

STEAM HEATING SYSTEMS

Object.—To study the construction and operating principles of a steam heating system.

Directions.—Make arrangements with your instructor for making a study of the steam heating system employed in the school building in

which you are located or another building in which such a system is used. The engineer in charge of the building will no doubt help you, if proper arrangements are made.

Proceed as directed in your study of the hot air furnace and hot water systems. You will find many modifications from that form used in the hot water system.

Locate the water gauge. What is its purpose? Locate the safety valve. What is its purpose? Locate the steam chest. What is its purpose? Locate the pipes leading from the steam chest. Where do they conduct the steam? Where does the condensed steam or water return? Is the steam conducted to the various rooms or to a single chamber through which air is blown? How does the heated air reach the rooms? Is any moisture added to the air after it is heated? Why? Is all the air heated or only part of it? Is this a good system for large buildings? Reason. Would it be a good system to use in small homes? Reasons.

Convection Currents Put to Work.—If we have a cold room how shall we proceed to warm it? If we want to set up a hot water heater or build a refrigerator, what scientific principles are to govern our actions? Many such questions force themselves upon us when we endeavor to solve the many problems that arise daily as we attempt to provide the conveniences required in our present-day method of living. A savage lived a very simple life which demanded few comforts and yet was full of hardship and artless makeshift. Our civilized life demands conveniences that are granted to us only when we are able to understand and make use of those principles that underlie the construction and operation of the tools and instruments that are to provide these greater comforts.

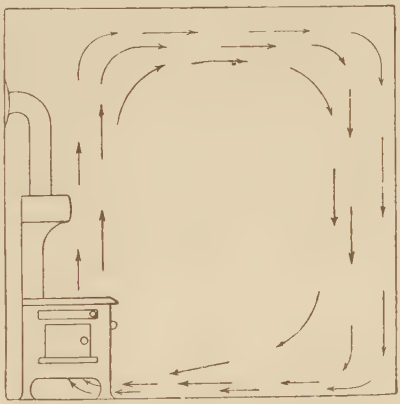


FIG. 58.—Convection currents in a room. (*From Tower, Smith, Turton, and Cope's Physics.*)

When we want to warm a room we set up a stove, connect it by means of a stovepipe to the chimney in the wall, build a fire within the stove, set drafts, and in due time the room is warmed. This is indeed simple, but do we understand the operation of this

simple device? How is it possible for the room to become warmed in the farthermost corners? The layer of air that is in contact with the sides of the stove, Fig. 58, becomes heated. Now we have learned from an experiment in the preceding chapter that when air is heated it expands and thus occupies more space. Therefore we can readily see why a tin box which holds just a cubic foot of cold air would lose some of it when heated. For as the air became heated, the air would expand, and a portion of it would have to leave the box. Consequently there is not so much air in our box when it is hot as when it is cold. Therefore we conclude that a cubic foot of warm air is lighter than a cubic foot of cold air when all conditions, excepting temperature, are the same. The actual weights of air that would be found in our cubical box at different temperatures are listed in the following table:

Temperatures, degrees Fahrenheit	Weight in pounds of a cubic foot of dry air at different temperatures	Weight in pounds of a cubic foot of air saturated with water vapor at the different temperatures
0	0.086	0.086379
22	0.0824	0.082302
32	0.0807	0.080504
42	0.0791	0.078840
62	0.0761	0.075581
72	0.0747	0.073921
92	0.0720	0.070717
102	0.0707	0.068897

Since the hot layer of air that surrounds the stove is not so heavy as the cold air farther out, the warm layer of air is forced to the top of the room. This movement of the warm air to the top of the room allows the cold air to approach the stove and become heated, which in its turn is replaced by the cooler and heavier air. Thus we have warm currents of air flowing to the top of the room with cooler currents flowing down the walls and over the floor to the stove. This continuous flow of the convection currents of air results in the carrying of heat to all parts of the room.

When we endeavor to heat with stoves rooms containing large numbers of people, such as are found in schools and churches, we find it difficult to provide equal comfort for all. In severe weather the stove is heated to a high temperature in attempting to warm all parts of the room. Under these conditions the stove throws off a very large amount of radiant heat, and the people who are seated near the stove are over heated, while those at the outer edges of the room are suffering with the cold. To prevent these effects of radiant heat a sheet iron jacket provided with a door is placed around the stove. There should be at least a foot and a half of air space between the jacket and the stove. The jacket should reach just above the stove and be supported at least eight inches from the floor. This jacket catches most of the radiant heat, helps to warm the cold currents of air that pass up between it and the stove, and greatly increases the effect of the convection currents which heat the outer edges and far corners of the room.

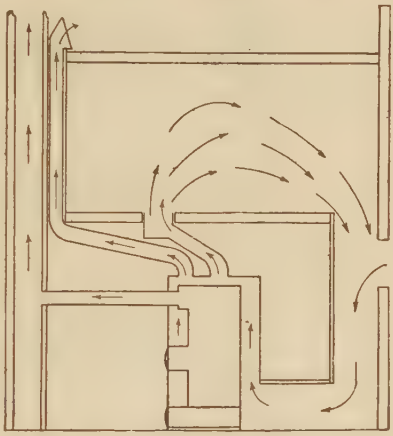


FIG. 59.—Heating and ventilating by means of a hot-air furnace. (*Tower, Smith, Turton, and Cope's Physics.*)

However, the presence of stoves in the living rooms of our homes, schoolrooms, and public auditoriums has long been considered an inconvenience and is always accompanied by the annoyance of fuel, ashes, dust, and smoke. In order to remove this inconvenience the "jacketed stove" is being removed to the basement. In this case, however, the jacket is closed at the top and bottom. The cold air is conducted to the bottom of the jacket by a large pipe called the cold air pipe or cold air shaft, while pipes at the top conduct the hot air into the rooms above as shown in Fig. 59. This heating arrangement is called a *hot air furnace* and is the cheapest heating system to install in small houses and similar buildings. The hot

air furnace not only provides a good circulation of warm air, but also furnishes a means of ventilation if some cold air is admitted to the furnace from the outside.

Hot Water Heating.—In large buildings the hot air furnace fails to provide even and sufficient heat, one part of the building being very hot while another may be very cold. To meet this objection *hot water* and *steam heating systems* are installed. In a general way the hot water system may be compared to a hot air furnace, for the operation of each depends upon the same principle. Just as warm air is lighter than cold air, warm water is lighter than cold water. Therefore we find the hot water being forced to rise to the top of the heater and up through the pipes to the radiators by the heavier cold water that is contained in the pipes that lead from the radiators to the bottom of the heater. While passing through the radiators the hot water gives up its heat to the radiators, which in turn heat the air in the room and thus produce convection currents precisely as a hot stove does. As the hot water is cooled it passes out the opposite end of the radiator and sinks through the return pipe leading to the bottom of the heater. Thus a continuous stream of cold water leaves the radiator for the bottom of the heater, while a continuous stream of hot water is forced out of the top of the heater toward the radiator. In this manner

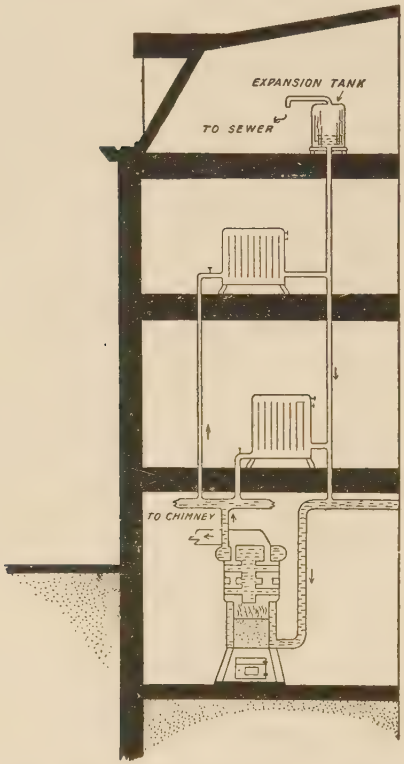


FIG. 60.—A hot-water system of heating. (*From Tower, Smith, Turton, and Cope's Physics.*)

Weight of Water per Cubic Foot for Various Temperatures

Temperature, Degrees Fahrenheit	Weight in Pounds per Cubic Foot
32	62.42
60	62.37
90	62.13
120	61.74
150	61.18
180	60.55
212	59.71
240	59.10

the circulating water (convection currents) carries the heat given it by the fire in the heater to all parts of the building. Hot water systems are provided with *expansion tanks*. Can you explain or give reasons for the provision of these expansion tanks in the hot water system?

Steam Heating.—In a *steam heating system* we find a heater, consisting of a furnace and boiler and a series of pipes and radiators. The whole arrangement of the parts is almost identical with the arrangement found in the hot water system. In the hot water system two sets of pipes were required, one for the escape of the hot water and one for the return of the cold water. In the steam heating systems we have a one-pipe system as shown in Fig. 61. However, the principles involved in the operation of hot water systems and steam heating systems are wholly different. In the steam heating system water is changed in the boiler to steam, which escapes through the pipes to the radiators; in the radiators the steam is changed back to water. Now when we change water to steam a great amount of heat is taken up. When this steam is changed back into water exactly the same amount of heat is given off as was taken up when the steam was formed in the boiler. The changing of water to steam is called *vaporization*, while the change of steam to water is called *condensation*. During the process of vaporization heat is taken up, and when condensation takes place the heat is given back.

When we change water to steam, the steam occupies a much larger space than the water from which it was formed. Indeed, one cubic foot of water fills 1660 cubic feet when changed to steam at a pressure of 15 pounds per square inch. As the

water is changed to steam, the steam pressure increases very rapidly, and for this reason every steam boiler is supplied with a pressure gauge and a safety valve. The steam gauge indicates

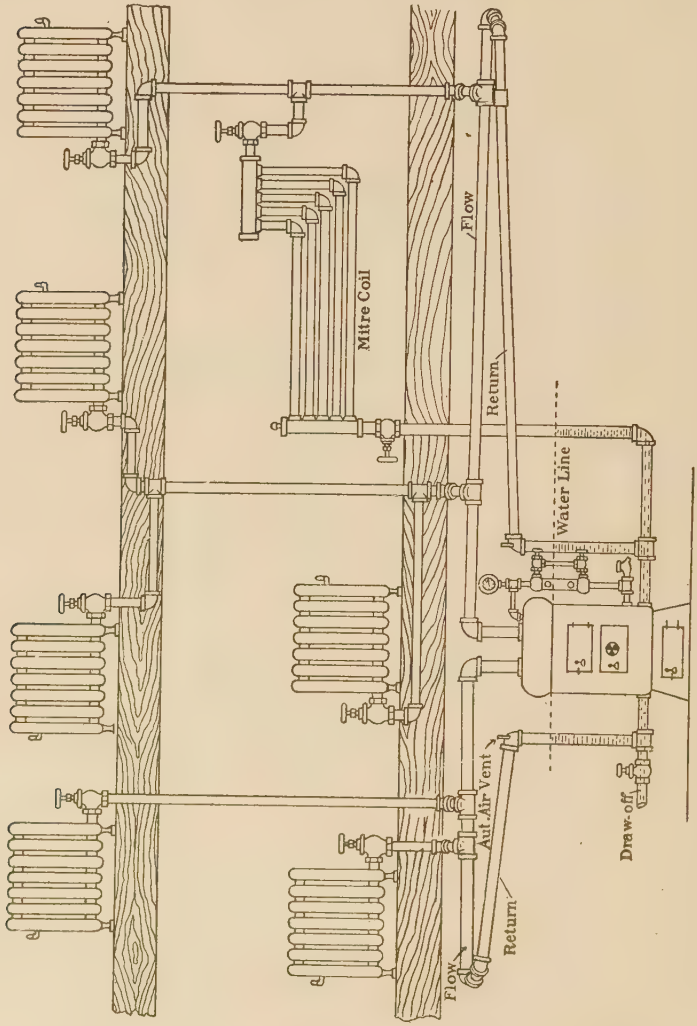


FIG. 61.—One-pipe system of steam heating. (*From Tower, Smith, Turton, and Cope's Physics.*)

the pounds of pressure per square inch on the inside walls of the boiler, while the safety valve allows some of the steam to escape when the pressure becomes too great for safety. As the steam rushes into the radiator it condenses and gives up its

heat to the radiator, which in its turn gives up the heat to the room in the same manner as a hot water radiator does. The condensed water collects at the bottom of the radiator, and since it occupies so little space and is 1660 times as heavy as the same volume of steam, it flows down one side of the pipe that leads the steam to the radiators. That is, we have two streams, steam and water, flowing in opposite directions through the same pipe—the water toward the boiler to be reheated and

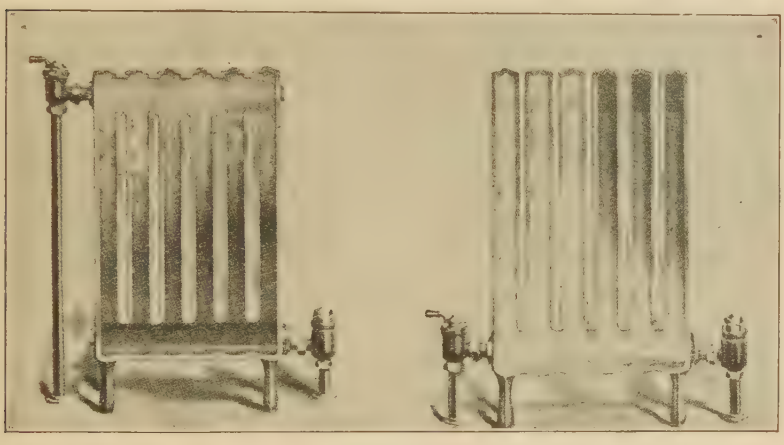


FIG. 62.—Circulation and condensation of steam in radiator. In one case the steam enters at the top and escapes at the bottom. In the other it enters and escapes at the bottom. Which type of radiator do you think is more efficient? Why? (*From The Webster Co.*)

vaporized, the steam toward the radiators to be cooled and condensed. The making of steam in the boiler tends to increase the pressure, and the condensing of steam in the radiators tends to decrease the pressure, the result being that heat is transferred from the boiler to the radiators that are distributed throughout the system.

Steam heating is the best system to use when we endeavor to heat large buildings, since hot water and hot air cannot be economically carried long distances. Schools and colleges, wherein several large buildings are to be heated, make use of a central heating plant, from which steam is conducted in underground pipes to the various buildings about the campus. In some cities whole sections are heated from a central steam

heating station. The disadvantage of hot water and steam heating systems is that there is no provision for a constant supply of fresh air and moisture.

Projects

1. To determine how the temperature of the various rooms of large buildings is controlled and regulated by a system of thermostats.

2. To determine the heating costs per room for the home and to compare them with those reported from other homes.

3. To take care of the heating system in the home for a month and to report a set of regulations for its care and operation in order to obtain the best results.

4. To learn the kinds of fuel and methods of house warming in Buenos Aires, South America.

5. To report on methods employed for heating by electricity and to compare the cost and success of such systems with those now employed.

6. To look up the laws, rules, and regulations concerning the inspection of steam heating systems in apartment dwellings and public buildings in the city and to learn whether these rules and regulations are being enforced.

UNIT II

THE SEA OF AIR IN WHICH WE LIVE AND HOW IT SERVES US

CHAPTER VIII

PROPERTIES OF THE AIR AND THE USE THAT WE MAKE OF THEM

Object.—To make a study of the properties of the air in order to understand better the conditions necessary for the application of its several properties to everyday life.

How Things Make Themselves Known to Us.—Early in life we become familiar with such substances as iron, stone, wood, sand, water, and oil. The reason for this early acquaintanceship is that we are able to play and work with these solid or liquid materials in many ways and under various conditions. The things which we can grasp with the hand, view with the eye, and taste with the tongue appeal to us more strongly than those that we can not so use. During our work or play we gain a knowledge of things through our special senses—sight, taste, hearing, smell, and touch.

Now in an earlier chapter we prepared and worked with oxygen, hydrogen, carbon dioxide, and nitrogen. These four substances were more or less difficult for us to become thoroughly acquainted with, because they were colorless, odorless, and tasteless, and we could neither grasp them in our hands nor pound them together to produce sounds. These four materials represent a class of substances called gases and escape the observation of most people who have not had their attention especially directed to them.

The great ocean of air that covers the earth makes itself known to us in many ways and serves us in many instances. The greatest service that air renders is its constant supply of oxygen, which is the vital element in all life processes. Man

may live without food for forty days, without water for four days, but when he ceases to breathe for four minutes he is dead. The air serves us as a cushion to ride upon in the tires of bicycles and automobiles, as a control in our door checks, and as a means for setting the brakes on our street cars and railroad trains. The air plays a part in the operation of pumps, vacuum cleaners, diving bells, caissons, door checks, sand blasts, airplanes, windmills, and in numerous other devices related to the labors of man.

It is the purpose of the following exercises to point out the several properties of air and the particular applications of these properties in the arts of man.

AIR AND SPACE

Object.—To devise means for determining whether air does or does not occupy space.

Apparatus.—Glass tumbler. Large glass jar. A bottle fitted with cork. Funnel.

Materials.—A supply of water.

Procedure and Observation.—Grasp the tumbler by the bottom and

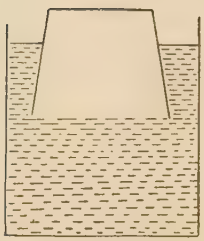


Fig. 63.—Inverted tumbler in jar of water.

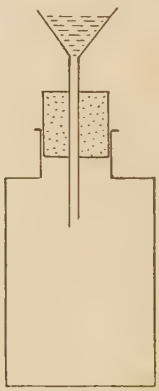


Fig. 64.—Arrangement of apparatus.

while inverted press it down in a vessel of water as shown in Fig. 63. Does the water rise in the tumbler and fill it?

Slant the glass enough to allow a bubble to escape. What is in the bubble? As the bubble escapes does the water rise in the tumbler? Allow another bubble to escape and repeat the observation. What is your conclusion regarding air and space?

Pass the stem of the funnel through a hole that has been made in the cork and arrange apparatus as shown in Fig. 64. Fill the funnel with water and observe results. Loosen the cork slightly and observe results. Does air occupy space?

Report your observations for each step and your final conclusion regarding air and its relation to space.

IS AIR COMPRESSIBLE AND ELASTIC?

Object.—To produce conditions and means whereby it may be determined whether air is compressible and elastic.

Apparatus.—Glass tumbler. Large glass vessel. Bicycle pump. Exhaust pump. Bell jar. Toy balloon. Foot ball. Pan. Quart jar.

Material.—Water.

Procedure and Observations.—(*a*) Hold the inverted tumbler just below the surface of the water in the larger vessel. Observe the level of the water within the glass. Still keeping the glass inverted, plunge it to the bottom, observing closely whether or not the level of the water has risen within the tumbler. Has the weight of the water compressed the air into a smaller volume?

(*b*) Slowly raise the inverted glass and observe closely the effect on the water level within the glass. Does the air seem to expand and drive the water out as the inverted glass nears the surface? Is the air elastic or does it remain in the compressed state? Record observations and conclusions.

(*c*) Examine the construction of a bicycle pump. Connect the pump with a basket ball and proceed to inflate the ball. From time to time examine the surface of the ball with your fingers. As more and more air is forced into the ball does the surface spring back more readily when depressed? After you have inflated the basket ball to a suitable degree, pinch the stem of the bladder and remove the compression pump, and insert a glass tube. Fill a quart jar with water and invert as shown in Fig. 65. Allow the air to escape slowly into the quart jar. When the bubbles have driven out all the water pinch the stem of the bladder to stop the flow of air. Fill and invert the bottle again and see how many times the air in the foot ball will fill the quart jar. Is this number of quarts greater than the volume of the foot ball? Do you conclude that air was compressed? Explain. Do you conclude air to be elastic? Explain.

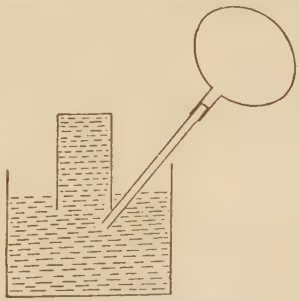


Fig. 65.—Arrangement of apparatus for measuring the air within an inflated bladder of a bootball.

(*d*) Fill the toy balloon about one-fourth full of air and close it with a string. Place the limp balloon under the bell jar which stands on the

receiver of an exhaust pump. Exhaust the air and observe the effects produced within the balloon. What is your conclusion about the elastic force of air? What would the air within the balloon have done had it not been so confined? Sometimes this *elastic* property of air is referred to as the "spring" of air.

Is this "elastic" property or the "spring" of air ever used for practical purposes? Explain.

Enumerate several uses made of compressed air.

Does compressed air ever take the place of springs? Give examples.

AIR AND WEIGHT

Object.—To learn whether a given amount of air possesses the property of weight.

Apparatus.—Scales, weights. Large electric light globe. Foot ball. Bicycle pump.

Procedure and Observation.

(*a*) Obtain a large burned out electric light globe. Weigh the globe accurately, leaving the weights on the scale. Remove the globe and by means of a blow pipe direct a flame against the glass bulb. As the glass softens note the effects produced. Why does the softened glass sink inwardly? Continue the heating until the softened glass gives way and thus allows the globe to fill with air. Set the globe on the scales. Is it lighter or heavier? Explain. Record your conclusion stating whether air possesses or does not possess the property of weight.

(*b*) Weigh accurately the empty foot ball, then inflate to a fair degree of hardness and weigh again. Record your observations and conclusion regarding air and weight.

AIR AND PRESSURE

Object.—To determine the possibility of the rise of pressures and forces from the weight of the ocean of air that envelopes the earth.

Apparatus.—(*a*) (For student). Glass tube. Bottle fitted with one hole rubber stopper. Medicine dropper. Pipe or funnel. Glass squares. Glass tumbler.

(*b*) (For teacher) Palm glass. Magdeburg hemispheres. Exhaust pump.

Materials.—Rubber sheet. Thread or rubber bands.

Procedure.—(*a*) Studies for the students. (*b*) Demonstration by teacher.

(Part *a*)

1. Fill the bottle with water and tightly fit the cork and tube as shown in Fig. 66. Place the lips to the end of the tube and endeavor to draw the water up into your mouth. If you do not succeed try again. Are you

able to draw the water out? Loosen the cork and try again. Can you see any reason why you obtain different results for the two attempts? You produced a suction effect in the end of the tube in each case and yet in the one there was no result. What forced the water to rise up the tube in the one case? Explain by means of a simple drawing with arrows indicating forces.

2. Fill the tumbler partly full of water. Place a square of paper over the top of the tumbler. Holding the paper in place with one hand, invert the tumbler of water with the other. Carefully withdraw the hand holding the paper to the mouth of the tumbler. If the trial was well done no water should run from between the paper and tumbler. Explain the presence of forces that hold the paper and tumbler together and thus prevent the escape of water.

3. Fill the medicine dropper in the usual manner. Account for the causes of all the effects that you observe.

4. By means of thread or rubber bands fit a square of rubber sheet over the bowl of a pipe or the mouth of a funnel. Apply your lips to the stem and draw out the air. Account for the causes of the observed results.

5. Moisten the glass squares. Lay one on the other. Endeavor to separate them. What force is pressing the glass squares together?

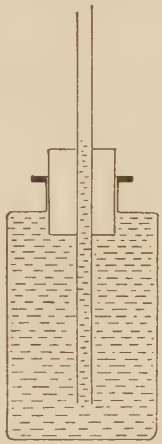


FIG. 66.—Arrange apparatus as shown and proceed as directed in experiment.

(Part *b*)

1. Place palm glass on receiver of exhaust pump. Allow pupils to experience the suction effect due to atmospheric pressure by covering the palm glass with their hands.

2. Exhaust air from the Magdeburg hemispheres and have pupils make an attempt to pull the hemispheres apart.

Record observations and conclusions.

TORRICELLI'S EXPERIMENT. (TEACHER'S DEMONSTRATION)

Object.—To learn how Torricelli measured accurately the pressure of the air.

APPARATUS.—34-inch glass tube sealed at one end. Mercury. Bowl. Yard stick. Tall bell jar. Exhaust pump.

PROCEDURE.—Completely fill the dry tube with clean mercury. Keeping the open end securely closed with the finger, invert, and insert finger and end of tube together below the surface of the mercury in the bowl. Keeping the finger in place observe the height of the mercury in the tube.

Remove the finger and observe result. Measure height of mercury. Have volunteers explain causes of results.

Place all under the tall bell jar and exhaust the air. Observe and account for results.

Admit the air, observe and account for results.

What is a mercury barometer? How is it affected by altitude?

Observe the barometer for 10 days and record the readings along with other facts required in the following exercise.

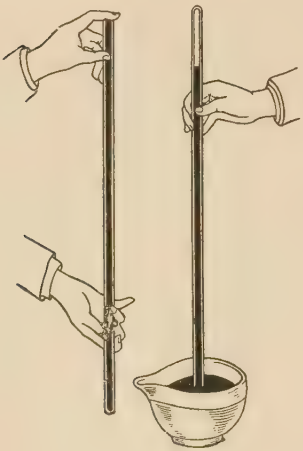


FIG. 67.—Torricelli's experiment. (*From Tower, Smith, Turton, and Cope's Physics.*)

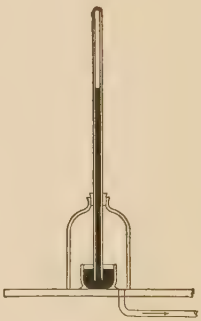


FIG. 68.—The mercury drops as the air is removed. (*From Tower, Smith, Turton, and Cope's Physics.*)

BAROMETER AND WEATHER

(Work in this exercise is to be started at this time and completed as an introductory exercise in Chapter X)

Object.—To make daily readings of the barometer and to observe the character of the weather in order to discover a possible relationship between these readings and the observed weather conditions.

APPARATUS.—Wall barometer. Outside thermometer, if possible maximum and minimum thermometers. Daily weather map on bulletin board.

PROCEDURE.—In your record or laboratory book plan and rule a table similar to the one here given.

Date	Hour	Temperature out of doors at time of reading	Wind		Character of weather	Indications
			Direction	Velocity		

The readings and observations should be made at a given time each day.

Indicate the character of the weather as follows: ○, Fair; ◐, Partly cloudy; ●, Cloudy; R, Rain; S, Snow.

Indicate wind direction by arrows flying with the wind. The top of the page is north; the right, east; etc.

Record wind velocity as follows:

Light, when just moving the leaves of trees.

Moderate, when just moving the small branches of trees.

Brisk, when moving the large branches.

High, when swaying the tree and blowing dust and papers from the ground.

Gale, when breaking the small branches from the trees.

OBSERVATIONS.—After you have kept the record for 10 days study your table as follows:

Do you observe any relation between the barometer readings and the temperature?

Do you observe any relation between temperature and direction of wind?

At the beginning of a clear period was the barometer high or low?

At the beginning of a cloudy or storm period was the barometer high or low?

In your locality from what direction do most of the winds come? The storms?

Is the barometer a serviceable instrument in the art of weather forecasting? Explain.

Do you consider the services of a Weather Bureau of any importance? Explain your answer by giving instances.

What is an isobar? An isotherm? Obtain a weather map and locate the isobars and isotherms.

AIR AND SOUND

Object.—To learn the relationship of the air to the sounds that we hear.

Apparatus.—Tuning fork. Dish. Meter stick or yard stick. Bottle with narrow neck, or test tube. Phonograph and phonograph record. Reading glass or large magnifying lense. Exhaust pump and bell jar. Electric bell. Dry battery.

Materials.—Water. A roll of cotton or a paper sack full of excelsior.

Procedure and Observations.—1. Set the tuning fork in motion by plucking its prongs with your fingers. Are the prongs in rapid vibration? Touch the surface of the water in the dish with one of the vibrating prongs and observe the effect. Is there a wave motion set up in the surface of the liquid? Bring the vibrating fork toward the edge of the dish so that one prong just touches the side or edge of the dish, and note the effect. How can you tell when the fork stops vibrating?

2. Have a person hold the vibrating fork at the distance of one yard from your ear and observe closely the effect, and then have the stem of the fork pressed against one end of a yard stick the other end of which you are holding against your ear. In which case did the effects seem the more audible? Which is the better conductor of the vibration effects of the fork, air or wood? In which body has the vibrating fork set up the stronger motion, wood or air?

3. Blow across the top of a test tube or a tall and narrow bottle in such a manner as to cause a sound. Fill the tube one-fourth full of water and again blow across its mouth. Fill one-half and repeat. Fill three-quarters and repeat. In which case did you observe low tones? High tones? Which gives forth the higher tones, long columns of air or short columns of air? How can you tell when a column of air stops vibrating? Explain the use of the "slide" on a sliding trombone. Name other instruments that depend on vibrating columns of air.

4. By means of a reading glass or lense examine the surface of a phonograph record.

Can you find the groove in which the point of the needle rests? Is the groove smooth or does it seem to be made up of "waves" of various shapes and sizes? As the needle travels along in this groove what must be the effect on the point of the needle?

Set a needle in place and study the mechanism to which you have attached the needle.

Do you find a rod leading from the needle to the center of the disk-like object? What would be the effect on the rod and disk if the needle were caused to vibrate very rapidly? If the disk were set in rapid vibration would it set the column of air in the horn or sound box in motion?

Set the record on the machine, adjust the needle, and "play" the record. Play the record slowly. Rapidly. In which case do you obtain low

pitched tones? High pitched tones? In which case does the needle vibrate the more rapidly?

5. Demonstration by Teacher.—On the receiver of an exhaust pump so place an electric bell as to rest it upon a deep layer of cotton or other non-conducting sound materials. Connect with dry cell. Cover all with a large bell jar. Observe loudness of sound. Exhaust the air and observe loudness of sound. Admit the air slowly and note the growing intensity of the sound. If a perfect vacuum could be obtained, what would be the result? Draw your conclusion about air as a medium for the transmission of sound.

6. Summarize the relation of air to the sounds we hear by:

(*a*) contrasting air and wood as carriers of sound,

(*b*) showing the relation of vibrating columns of air to high and low pitched tones,

(*c*) and showing the relationship of vibration rate to the pitch of the sound.

The Atmosphere and Its Relation to the Earth.—The whole globe of the earth is surrounded by a fluid called air, which,

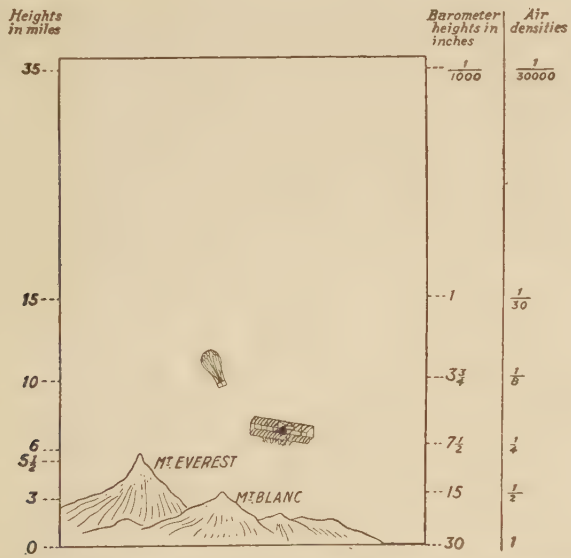


Fig. 69.—Height and density of the air. (*From Tower, Smith, Turton, and Cope's Physics.*)

though not perceived by our eyes, is manifested and made known to us in various ways. As fishes are surrounded by water, and live and move in water, so we human beings and

all other animals are surrounded by air and live and move in air. This ocean of air in which we live and move extends to a height of many miles above us, and the whole mass of it is called the *atmosphere*.

While we may liken the earth's atmosphere to a great ocean of water, there are particulars in which air differs greatly from water. The greatest of these differences is that water is not compressible, whereas a quantity of air may be compressed to a very small volume. Since in one of the introductory experiments we proved that air has weight, we can easily understand how the weight of the upper layers of the atmosphere compresses the lower layers, and hence how the layers of air at or near sea level are more greatly compressed than those that lie above. Again, since the lower layers of air are the more compressed they are the more dense, and since the higher layers are less and less compressed, they are, therefore, less and less dense. This is also expressed by saying that the upper layers are more *rarefied* or more rare. In a statement that air in a lecture hall, 100 × 50 × 25 feet, weighs about 5 tons, it is understood that air at or near sea level is referred to. At any greater height a similar volume of air will weigh less on account of the fact that not so much air would be compressed into this space. Furthermore, it is easy to conceive that the great mass of air which constitutes the atmosphere must exert a great pressure on the surface of the earth and all bodies thereon.

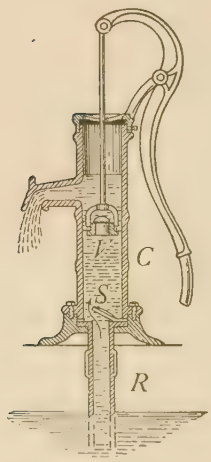


FIG. 70.—The common lift pump. (*From Tower, Smith, Turton, and Cope's Physics.*)

Air Pressure and the Lift Pump.—If the lower end of a long tube be dipped into water and the air drawn out through the upper end, the water will rise in the tube. Every time we draw lemonade or milk through a straw we prove the truth of the above statement, and it is probable that each and every one of us has performed this act and similar acts without ever thinking that the atmospheric pressure played a part in the undertaking.

Now the common lift pump, Fig. 70, known and used since the days of Aristotle, depends upon the atmospheric pressure to raise the water in the suction pipe, *R*. The success of such a lift pump depends upon two air-tight valves, one of which, *S*, is fixed to the top of the suction pipe, and the other, *V*, over the hole in a closely fitted piston head. Since these two valves will allow air (or water) to pass by them in only one direction, it is possible by moving the piston up and down to draw out the air from within the cylinder and the suction pipe. This tendency to form a vacuum in the cylinder and suction pipe can never take place on account of the pressure of the air on the surface of the water in the well, which forces water up through the suction pipe. As more and more air is being withdrawn, the water is forced by the outside air pressure to rise higher within the suction pipe and finally through the valve, *S*, and into the cylinder of the pump. This is ordinarily the case, but we shall learn in the following paragraphs that there are some restrictions that must be taken into consideration when using this pump.

The Duke of Tuscany and Galileo.—In 1640 the Duke of Tuscany had a deep well dug near Florence and found that the best obtainable water pump would not raise the water higher than about 33 feet above the level of the water in the well. The kind of pump used was in every way similar to the one shown in Fig. 70. The suction pipe, *R*, extended a trifle over 40 feet down into the well in order to reach the water at the bottom. The Duke of Tuscany was disappointed as well as surprised to discover that water under no condition could be drawn to a greater height than 33 feet, and that a vacuum remained in the upper part of the pipe and cylinder into which the water would not rise. Now the Greek and Roman philosophers had taught that "Nature abhors a vacuum" so persistently that any attempt to form one would be quite useless. But the Duke of Tuscany had a vacuum in the top of the suction pipe, and no water would rise into it after reaching a level of about 33 feet.

Being unable to solve the mystery, the Duke of Tuscany made a visit to the aged Galileo, a noted philosopher of the times, and asked for an explanation. Galileo's answer was not very

satisfactory, for he replied, "'Nature's horror of a vacuum' does not extend beyond a height of 33 feet." It is quite likely that Galileo knew better than he answered, and that he suspected that the atmospheric pressure was in some way responsible, for he had proved before this time that air had weight and had planned experiments in order to test, as he said, the "power of a vacuum." However, he was too old and feeble to carry out his plans, but suggested to his pupil and friend, Torricelli, that he take up the work and endeavor to solve the problem.

Torricelli's Experiment.—Shortly after Torricelli had taken up the work suggested by Galileo, he came into possession of a quantity of mercury (quicksilver), which he found to be 13.6 times heavier than an equal volume of water. Now Torricelli argued that if water would rise in an exhausted tube to a height of 33 feet, mercury, which is 13.6 times heavier than water, ought to rise only $\frac{1}{13.6}$ as high, or about 30 inches. In order to prove the correctness of his reasonings he performed in 1643, one year after the death of Galileo, his famous experiment which is still known as Torricelli's experiment. He, accordingly, took a glass tube 33 inches in length and filled it completely with mercury. Covering the open end with his finger, he inverted the tube and submerged the open end beneath some mercury in a dish. When he withdrew his finger from the end thus submerged, the mercury within the tube sank to a level between 29 and 30 inches above the level of the mercury in the dish. Torricelli concluded from this experiment that liquids rise in exhausted tubes on account of an outside pressure exerted by the atmosphere on the surface of the liquid, and not on account of any mysterious sucking power created by the "suction of a vacuum," for in the upper end of his tube there was a very nearly perfect vacuum. From day to day Torricelli observed that the height of the mercury column often varied. He inferred that these variations were due to the changes in the pressure of the air, which was "now heavier and more dense, now lighter and less dense or thin."

Pascal Studies Torricelli's Experiment.—When Pascal (1623–1662) learned of Torricelli's experiments, he repeated them and

put them to various other tests in order to establish their truth or falsity. Pascal reasoned that if one were to ascend a mountain, the pressure of the air at the greater height should be less, because there would be less air overlying the mountain top than there was overlying an equal area of the plains at Paris or Florence. As there was no mountain near Paris, he carried Torricelli's apparatus to the top of a high tower and found, indeed, a very slight fall in the height of the mercury column. He then wrote to his brother-in-law, who lived near an ancient volcano, the Puy de Dome, in Auvergne, France, asking him to ascend the mountain with a Torricellian tube and observe whether the mercury column would fall because of the diminished air pressure. Perrier, the brother-in-law, wrote back (1648) that he had performed the experiment and that he was "ravished with admiration and astonishment," for he had found that when he had ascended the mountain to a height of about 3000 feet the mercury sank about 3 inches in the tube, and that the mercury column gradually resumed its former length during the descent to the plains of Auvergne.

Pascal also repeated Torricelli's experiment with other liquids. He took a tube closed at one end and nearly 40 feet long, filled it with water, and found that the water stood in the tube at a height of 34 feet, which is 13.6 times as high as the column of mercury in Torricelli's experiment. Pascal also repeated the experiment with oil and wine with similar results. However, these liquids, being lighter than water, stood at greater heights; for instance, the column of oil stood at a height of about 37 feet. Pascal's studies and experiments confirmed Torricelli's conclusion that the atmospheric pressure was responsible for the rise of liquids in exhausted tubes and the suction pipes of lift pumps. Since the atmospheric pressure could exert only a certain definite number of pounds of pressure, it could raise liquids to only a certain height. If the liquid were light like oil it took a tall column to equal the atmospheric pressure. If the liquid were heavy like mercury a short column only was required to balance the outside air pressure. In every case the weights of the columns of the liquids were the same. Thus the Duke of Tuscany's mystery of discovering water rising only

about 33 feet in the suction pipe of his pump was explained; the atmospheric pressure was unable to raise it any higher; or in other words a column of water 33 feet high exerts the same pressure per square inch as a similar column of the earth's atmosphere, which extends from the surface of the earth upward to the very limits of our air ocean. It has been found that the average daily pressure at sea level is about 15 (14.7) pounds per square inch.

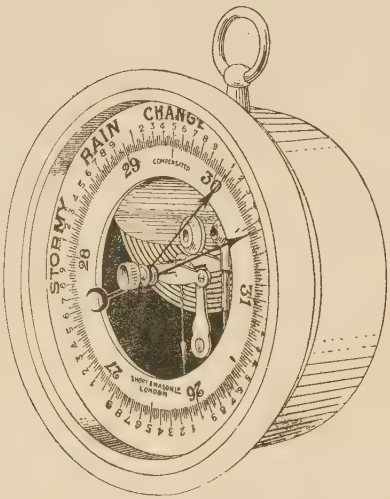


FIG. 71.—An aneroid barometer. (*From Tower, Smith, Turton, and Cope's Physics.*)

The Mercurial and Aneroid Barometers.—Our present barometer is essentially a Torricellian tube over a dish of mercury, all of which is properly mounted and provided with very accurate means for measuring the length of the mercury column. The mercurial barometer is the only reliable and trustworthy barometer yet brought into use, and for this reason is found in all weather stations and institutions that require accurate reading of atmospheric pressure.

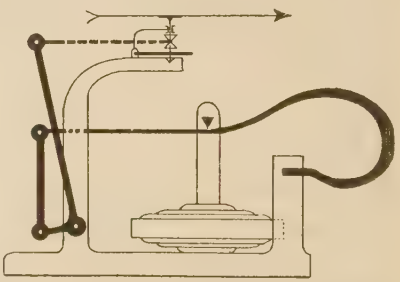


FIG. 72.—The mechanism of an aneroid barometer.

However, for carrying and traveling purposes the mercurial barometer is very inconvenient, because of its weight and length, so geological and surveying parties, aviators, and balloonists, who find it essential to determine the height of hills, mountains, and other altitudes make use of an instrument called the aneroid barometer. It consists essentially of an air-tight cylindrical box, Fig. 71, the top and bottom of which are metallic dia-

phragms which bend slightly under the influence of changes in the atmospheric pressure. When the atmospheric pressure increases, the diaphragms of the box are compressed inwardly, and when the atmospheric pressure becomes less, the diaphragms are allowed to spring apart. These motions on the part of the diaphragms are magnified and communicated by means of levers to a hand, Fig. 72, which moves over a dial whose readings are made to correspond to the readings of a mercurial barometer. These instruments are made so sensitive as to indicate a change in pressure when they are moved no farther than from the table to the floor.

The Barometer and Its Use as a Weather Instrument.—Because of disturbances in the atmosphere the barometer readings vary from 29 to 30 inches in localities not far from sea level. The Weather Bureau has observed that these disturbances of the atmosphere pass somewhat regularly across the United States in a general direction from west to east. These disturbances are recorded by the barometer as high or low readings. When the barometer reads high, it is understood that a high pressure disturbance is passing, and when the barometer reads low, a low pressure disturbance is passing. The barometer does not directly foretell the weather, but it has been found that low or rapidly falling pressure is usually accompanied or soon followed by stormy conditions, while a rising barometer generally indicates the approach of fair weather. The Weather Bureau has observations taken at the same moment at various stations throughout the country. From these observations it is possible to make a fairly reasonable and certain forecast of weather a day or two in advance.

The Force Pump.—The force pump, Fig. 73, is used to deliver water under pressure for spraying purposes or to elevated reservoirs. As shown in the figure, the piston head is solid, the second valve being placed at the mouth of a discharge pipe. The action of this pump is very much like that of the lift pump, with this exception: the piston in its downward stroke forces the water out through the discharge pipe. The discharge pipe is usually provided with an air chamber. On every down stroke of the piston the water is forced into the air chamber, *A*,

thus greatly compressing the air therein. The compressed air exerts a spring-like effect on the surface of the water and thus forces it out in a steady stream through the discharge pipe. The pumps used in city water works, fire engines, and all steam pumps are force pumps and are provided with large air domes that make possible a steady stream of water.

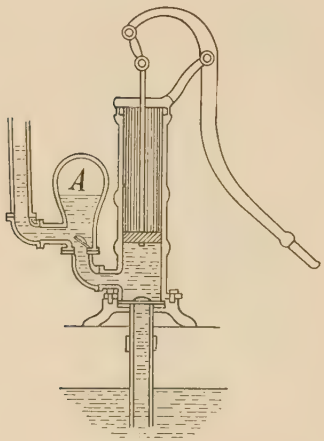


FIG. 73.—A force pump with an air chamber (*A*). (*From Tower, Smith, Turton, and Cope's Physics.*)

The Air Pump.—The air or exhaust pump is used to remove air or other gases from closed vessels. Otto Von Guericke of Magdeburg, Germany, invented (1650) the first air pump and the Magdeburg hemispheres. One form of air pump is shown in Fig. 74. In the cylinder, *C*, there is a tightly fitting piston with a valve *r*. The bottom of the cylinder connects with a bell jar, *R*, that fits well upon the receiving plate of the pump. The valves, *r* and *u*, both open upward and allow the air to pass only in one direction. Now every time the piston is moved up, there is a tendency to form a vacuum in the cylinder. This

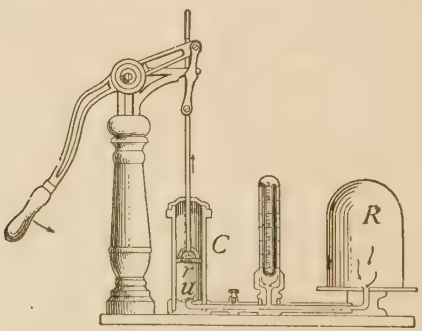


FIG. 74.—The air pump. (*From Tower, Smith, Turton, and Cope's Physics.*

vacuum can never occur, for the air or gas in *R* is elastic, or spring-like, and therefore expands into the cylinder *C* and fills it. Each and every stroke removes more and more air, but

can never remove all, for the remaining portion, no matter how rarefied, extends through all of *R*, the connecting tube, and the cylinder *C*. Thus only a partial vacuum can ever be accomplished by an air pump.

The Compression Pump.—This pump is like the exhaust pump except that it has its valves reversed. It is used for compressing illuminating gases into cylinders for use in lighting vehicles and gas light buoys, for compressing air with which to operate drills, pneumatic hammers, air brakes, and to fill tires on automobiles; indeed, wherever compressed air is needed, some form of the compression pump is necessary.

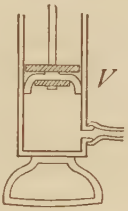


FIG. 75.—The compression pump. (*From Tower, Smith, Turton, and Cope's Physics.*)

The common compression or condensing pump is the kind used for filling bicycle tires. In this pump a metal piston is fitted with a leather disc somewhat larger than the cylinder. This kind of piston serves as a valve, known as a *cup valve*, Fig. 75. If the piston is raised, there is a tendency to form a vacuum below. The air is permitted to pass the leather cup and fills up the lower portion of the cylinder. But if the piston is pushed down, the cup opens up and presses very tightly against the sides of the cylinder and thus allows no air to escape. The compressed air pushes open a valve on the tire and enters it. The tire valve closes as soon as the piston starts up on a new stroke. In all of the pumps it is well to notice the necessity of two valves. Both valves are never open at the same instant. One holds the supply secure while the other opens for a new supply.

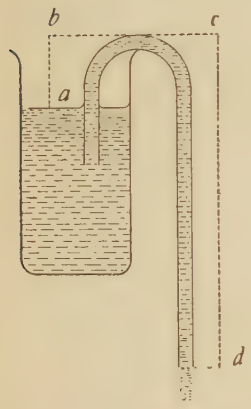


FIG. 76.—Cross-section of a siphon. (*From Tower, Smith, Turton, and Cope's Physics.*)

The Siphon and Its Relation to Air Pressure.—The siphon, Fig. 76, is a device for transferring liquids from one level over an elevation to a lower level and depends in its action upon the pressure of the air. The appa-

ratus consists of a tube, open at both ends, and so bent that one arm is longer than the other. When the tube is filled with liquid and then inverted, the shorter arm being placed beneath the surface of the liquid in the upper vessel, the liquid will flow from the longer arm.

The action of the siphon is explained as follows: The air pressure at *a* is approximately the same as that at *d*. But the air pressure at *a* is opposed by the weight of the short water column *ab*, while the air pressure at *d* is opposed by the weight of the greater water column *cd*, and hence this unbalancing of forces results in a flow of water from the end of the longer arm. The liquid will continue to flow as long as there is a difference of levels of the liquids in the upper and lower vessels, or until the level of the liquid in the upper vessel descends below the end of the shorter arm. A second condition necessary to the action of the siphon is that for water the height of the bend jar must not be greater than 33 feet above the level of the water in the upper vessel; for mercury, not more than 29 inches. Why?

Compressed Air and Its Uses.—The fact that air can be compressed into a very small space and still retain its elastic or spring-like qualities makes it very serviceable in our present-day arts. We compress it into pneumatic tires upon our bicycles, carriages, and automobiles, where it serves as a most efficient cushion to ride upon. Because of the fact that air is compressible and yet exerts its spring-like character with great force, we use it in air brakes to control or stop our railroad trains and street cars. We pump it through long tubes to operate our railroad signals, to push mail bags and express packages to various parts of our cities, to drive the cash boxes in large department stores, and to operate bells or whistles or many other similar devices in every corner of the world.

When great bridges are to be built across broad rivers, it often becomes necessary to erect piers in midstream. To construct such piers their foundations must be laid on the bed rock under the stream or river, and in order to do this, large caissons, Fig. 77, are constructed and the water is kept out of the working chamber, *A*, by means of compressed air. The

compressed air is forced in through the pipe, *G*, and thence down the air tight shaft, *B*, to the working chamber.

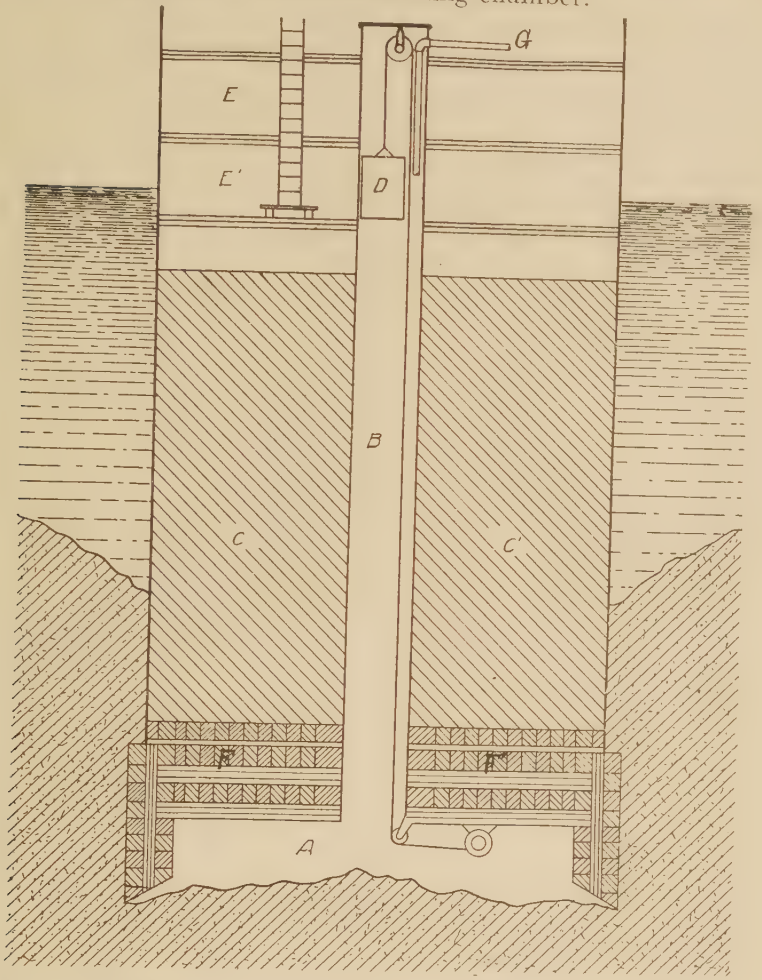


FIG. 77.—Caissons. *A*, The working chamber where excavation goes on in an atmosphere of such density (and pressure) that water from without is kept from entering; *B*, air-tight shaft through which workmen and material pass up and down; *E*, *E'*, chambers through which workmen pass to and fro from the cage, and where the atmospheric pressure to which they are subjected is gradually changed; *F*, *F'*, ballast of masonry to keep caisson in place; *G*, pipe conveying air under great pressure into the caisson chambers. (*From Brownell's General Science.*)

The men can not go immediately to work in the working chamber. The workmen must first go to chamber *E*, where the

air is gradually put under pressure, and then finally to E', in order that their bodies may become gradually adjusted to the compressed air in which they are to work. When leaving the caisson they must again leave by chambers E' and E and again allow their bodies to become adjusted to conditions outside the caisson.

If a workman fails to take time to allow the proper adjustment to be made, he is likely to suffer great bodily harm. Many cavities of the body are filled with air which presses against the walls of the cavities with a force equal to pressure of the air on the outside of the body. Under ordinary conditions, atmospheric changes are so slight and take place so gradually that we suffer no ill effects, for our bodies are able to make adjustments between the internal and external pressures as they take place from day to day. However, when a workman is to go to work in a caisson where the compressed air is likely to be under pressures ranging from 50 to 65 pounds per square inch, it is necessary that he make the change very gradually in order that his body may make adjustments for these great pressures. Otherwise if he entered a chamber of highly compressed air, the air in his body cavities would become so greatly compressed as to cause death. Again, if a workman should suddenly leave a chamber in which the air was greatly compressed, the air in his body would create internal pressures greater than the external. Such differences between internal and external pressures within and without the body would cause severe hemorrhages to take place and thus cost the workman his life. When the changes are made gradually from low to high or from high to low pressure, no ill effects are experienced.

Vacuums Put to Work.—When a stone on the end of a string is twirled rapidly, there is a great tendency on the part of the stone to break away and to fly off into space. When oil or water is poured near the center of a rapidly revolving wheel, the oil or water moves rapidly outward and is thrown with much force from the rim of the wheel. This force that pulls bodies away from the center of a rapidly revolving system is called centrifugal force.

Now when fan wheels are caused to revolve rapidly, the air is thrown off with much energy from the end of the blades of the fan. This flowing of air away from the outer edges of the fan causes a current of air to flow into the wheel at or near its center. As fast as the air enters at the center it is thrown off at the outer edge of the revolving fan, and hence a constant supply of air is flowing toward the central areas of the swiftly moving fan. This is the principle of the action of the vacuum cleaner, Fig. 78. In the section of the vacuum cleaner we can see the rapidly revolving fan and the current of air pressing into the fan near its axle or central portion and thrown off at the rim

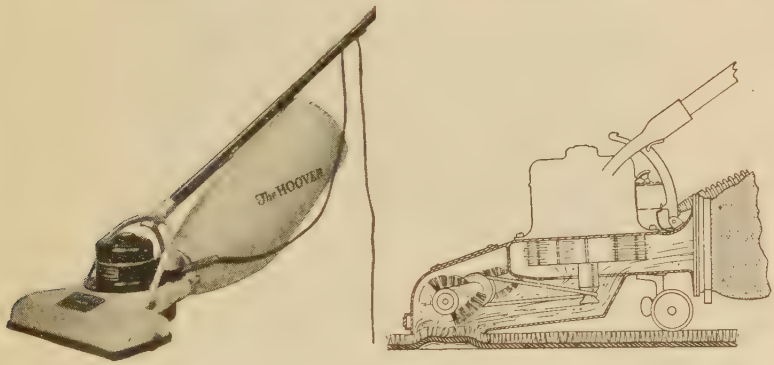


FIG. 78.—A vacuum sweeper. *(Courtesy of the Hoover Suction Sweeper Co.)*

and through a hole in the case to an attached dust receiving bag. When the nozzle of the vacuum cleaning machine rests against the surface of the rug, a partial vacuum is formed within the machine. The air rushes in between the fibers of the rug with enough force to carry along with it particles of dust and dirt into the dust receiving sack.

The Air, a Carrier of Sounds.—One of the many things that every infant soon learns is that he must shake his rattle, if he wants it to send forth sounds. Whenever one investigates the source of sounds he always finds that it can be traced to some vibrating body. Furthermore, these vibrating bodies are capable of setting other bodies in vibration. For instance, when the stem of a tuning fork is held in a dish of water or against the end of a yard stick, these bodies are set in vibration.

However, most of the sounds that we hear do not come to us through solids like wood or through liquids like water, but through the sea of air in which we live. This fact is nicely demonstrated to us when we put an alarm clock or an electrically operated bell on a cushion of cotton under a bell jar on the receiver of an air pump. When we exhaust the air the sound becomes more and more inaudible, and, if conditions are nearly perfect, the sound may actually become inaudible. However, the partial success of such a demonstration is enough to prove to us that air is a carrier of sounds. The demonstration also teaches us that sound can not travel through a vacuum.

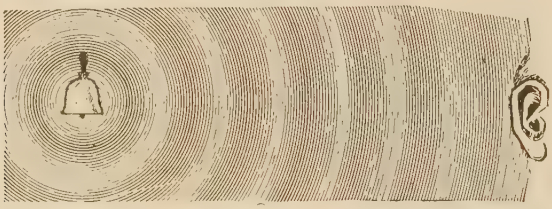


FIG. 79.—Sound waves spreading in all directions from the vibrating bell.

This is, perhaps, quite as we expected, for in a perfect vacuum there is no substance to be set into motion or vibration, and hence no sound is transmitted through it.

It is quite probable that the most of us, sometime in our lives, have stood by the edge of a quiet pool or lake of water, and that we have cast pebbles or stones into this body of water in order to watch the spreading circles of waves that ran away from the center of the disturbance. When a body like a tuning fork or a bell is set to vibrating in air, a motion quite similar to that of the waves of water is set up in our ocean of air. In air these wave-like motions consist of layers of compressed (condensed) and rarefied air as shown in Fig. 79. These layers of condensed and rarefied air run out from the vibrating body in much the same way that the spreading circles of water waves run out from the disturbances caused by the falling stones or pebbles.

How We Hear.—Now one of the most interesting things in nature is the provision of the special senses in the higher forms of life. The special sense of hearing concerns us here for the

reason that most of the sounds that we hear come to us through the air. These sounds are received by the ear, which transmits them to the auditory nerve, which in its turn communicates them to the brain.

A close study of the ear shows it to be arranged in three parts. The *external ear* leads to the *tympanum* or *ear drum*. The *middle ear* contains the small bones that transmit the vibrations of the tympanum to the *internal ear*. The internal ear is filled with a liquid which conveys the vibrations to a coiled-like

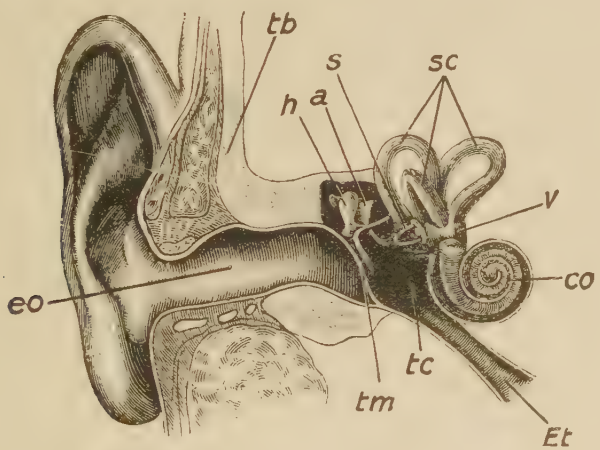


FIG. 80.—Section through the ear; *a*, anvil; *h*, hammer; *s*, stirrup; *co*, cochlea; *eo*, external opening; *Et*, Eustachian tube; *tb*, temporal bone; *tc*, tympanic cavity; *tm*, tympanic membrane; *v*, vestibule.

structure called the *Cochlea*. It is within the Cochlea that we find a delicate and wonderful arrangement of some 3000 hair like fibers or cords. It is believed that each fiber or string is sensitive to a particular vibration rate, and that each is attached to a particular nerve fiber. Referring to these hair-like strings within the Cochlea, Tyndall writes: "Within the ears of men has existed for ages a lute of 3000 strings accepting the music of the outer world and rendering it fit for reception by the brain. And thus, no matter how complicated the vibrations of air may be, these microscopic strings can analyze them and reveal the constituents of which the sound is composed."

Furthermore, by means of the ear we can in some way tell in what direction the source of the sound lies. We can recognize

differences in the pitch of sounds, some seeming high, others low and deep. We are able to recognize differences in intensity of sounds, some soft and weak, others loud and strong. We are able to distinguish differences in quality of sounds, i.e., the tone of a piano from that of a violin, the several voices of friends who are not in view. In short, the ear is one of the few great gate ways of the brain. Its care and well-being demand our constant attention and best judgment.

Musical Instruments.—The drum, the flute, and the violin represent the three classes of musical instruments. The drum represents a class of instruments in which sound is produced by a vibrating membrane; the flute, by vibrating air columns; and the violin, by vibrating strings. Now any or all of these instruments may be sounded in such a manner as to produce sounds that are in no manner musical and when so used are simply giving forth sounds that are called *noises*.

What is the difference between a musical sound and a noise? When a piano string or a tuning fork is set in motion, it is found that vibrations which are received by the ear follow each other at regular intervals, producing a musical sound. But a wagon bumping over a rough pavement is producing a set of vibrations that follow each other at very irregular intervals, and such a sound is characterized as a noise.

Now musical instruments are devices for producing musical tones. These tones differ from one another in three ways, viz., *intensity*, *pitch*, and *quality*. When a string is struck gently and again harder, the two sounds differ only in intensity or loudness. When a string is simply stretched between two nails, the sound may not be very intense. However, should the same string be stretched over a hole in a box and again vibrated, the sound may be heard throughout the room. The same principle for increasing intensity is employed in the sounding boards in pianos, violins, and various other instruments.

Pitch has to do with the number of vibrations that strike the ear per second. When the phonograph record is played slowly, a certain number of vibrations reach the ear in one second. When the record is played with greater speed, more vibrations reach the ear in a second of time. The faster we

play the record, the higher is the pitch, for a greater number of vibrations reach the ear in a given time.

Quality is the characteristic of a tone that tells the nature of the instrument sending forth the vibrations. By means of quality we are able to distinguish between tones of the same intensity and pitch, yet sent forth by two different instruments. We can easily tell the tones sent forth by a violin from those sent forth by a piano; indeed, the same instrument may send forth notes of different quality. The difference in the quality of the tones produced by two violins makes one very valuable and the other quite worthless.

Our Voice.—Of all the instruments for producing sound the organ of the voice is the most perfect. The vocal organ in man is placed at the top of the trachea or wind pipe, and contains two nicely adjusted elastic bands which almost close its opening. The two elastic bands are known as the *vocal cords*, and when the air of the lungs is forced through the slit which separates these vocal cords they are thrown into vibration. When we tighten the vocal cords we raise the pitch of the sound of the voice, and when we relax the bands we lower the pitch of the voice. The cavities of the mouth and nose act like sounding boxes for increasing the intensity or loudness of the voice. The tongue and the teeth are also used to modify and change the sounds emerging from the vocal chords. The promptness and accuracy with which the vocal chords can change their tension, their form, and the width of the slit between them render the organ of the voice the most perfect of musical instruments.

Projects

1. To make a simple Cartesian diver and to explain the principles underlying its operation.
2. To make a study of a siphon and to describe the many uses to which it may be applied.
3. To make a model lift pump in order to demonstrate the principles underlying its operation.
4. To make and demonstrate a model force pump in order to show the necessity of an air dome on this kind of pump.
5. To set forth by means of drawings the necessity of at least two valves in valve operating pumps.
6. To make and demonstrate a model air brake.
7. To write a paper on "The History of the Development of the Airplane."

8. To write a paper on "The Airplane and Its Relation to Travel and Commerce."

9. To write a biographical sketch of "Langley and the First Airplane."

10. To write a biographical sketch of "The Wright Brothers and Their First Airplanes."

11. To write a paper on "The Broom versus the Vacuum Sweeper."

12. To write a biographical sketch on "Otto Von Gurlicke and His Water Barometer."

13. To write a biographical sketch on "Otto Von Gurlicke; His Air Pumps and Magdeberg Hemispheres."

14. To write a paper on "The Uses of Compressed Air."

15. To exhibit and demonstrate some machine that operates by means of compressed air.

16. To write a biographical sketch on "Edison and the First Phonograph."

17. To write a theme on "How the Phonograph Record is Made."

18. To write a theme on "The Part Played by Gases in the Firing of Cannons."

19. To demonstrate the construction and operation of a "sliding trombone."

20. To write a paper on and to demonstrate "The Differences between a Musical Sound and a Noise."

21. To write a paper on "The Care of the Ear and the Vocal Cords."

22. To make a wall chart of the musical scale which sets forth the name, letter, and number of vibrations, and to demonstrate the uses of such a musical scale.

CHAPTER IX

MOISTURE IN THE AIR AND ITS RELATION TO OUR COMFORT

Object.—1. To make a study of the conditions governing the presence and the various forms of moisture in the air.

2. To make a study of the effects that varying amounts of water vapor in the air have upon our comfort.

Causes Bring about Effects.—Young children are continually asking their parents or other persons to explain the causes of the many incidents and happenings that take place about them. When properly developed this is a good habit that brings to the questioning child a great deal of worthy information. Many of us have asked our parents or friends concerning the fog, dew, frost, clouds, rain drops, snow flakes, or hail, and it is quite probable that most of these people have labored in an earnest way to tell us all about the causes that bring about these occurrences.

Again, in our play days we learned that every result or effect was due to some cause. However, in some instances the causes seemed hidden, or when partly discovered were hard to understand. For example, a boy sees a pitcher containing warm water standing by another pitcher containing ice water, and upon close examination discovers that the pitcher containing the ice water has a heavy layer of moisture on the outside surface. He gets a towel and dries the surface of the pitcher. A few moments later he observes the cold pitcher to be again covered with a deep layer of moisture, while the outer surface of the warm pitcher remains dry. The boy sees the effects, and then he wonders about "the reason for" or "the cause of" effects. Perhaps he thinks the cold pitcher has a crack through which the water comes and so he searches for it. He finds no crack. He can find no reason or cause for what he sees. He makes inquiry of some friend, who informs him that the moisture comes from out of the air about the pitcher. This is a new mystery. Why did

not the moisture settle on the warm pitcher? His friend replies that "moisture never settles on warm pitchers." This is another mystery. Now what is this boy going to do? Is he going to keep on searching and investigating until he is well informed and knows all the reasons and the causes, or is he going to let the matter stand in mystery and doubt? As a matter of fact, the majority of people are content to allow occurrences to remain half explained and half in doubt. On the other hand, there are a few people who desire to know thoroughly and from every point of view the "why and wherefore" of the many interesting occurrences that daily come within their experiences and observations.

When we "perform experiments" in general science or any other science, we simply produce conditions that bring about certain results. Now when we produce the same conditions time after time, we expect the same results. However, when we produce new and different conditions, we expect new and different results. The same thing is true in nature—that is, the same conditions always produce the same results, and when the conditions or causes are varied the results or effects are also varied. And so when we "perform experiments," we must always take into account the conditions. A full knowledge of causes enables us to know much about the results that we observe. In the suggested experiments that follow, always bear in mind the conditions that you set up when looking for certain results. In drawing conclusions give the condition or set of conditions that brought about the observed results.

EVAPORATION. (HOME PREPARATION)

Object.—To make a study of the factors affecting the rate of evaporation.

Apparatus.—Seven similar cups or glasses. Plate or shallow dish. Jar.

Materials.—Water. Gasoline or alcohol.

Procedure and Observations.

Factor 1. Temperature and Rate of Evaporation.—Place four tablespoonfuls of water in two cups or drinking glasses. Place one cup in a warm place and the other in a cool place.

Observe every hour and finally write a statement concerning the effect of temperature on the rate of evaporation.

FACTOR 2. AIR CURRENTS AND RATE OF EVAPORATION.—Place four tablespoonfuls of water in each of the cups and place side by side in some place where a draft can blow over them. Cover one of the cups with a jar or bowl so as to shut off all air currents.

Observe every hour or so until you are able to draw a conclusion concerning the effect of air currents on the rate of evaporation.

FACTOR 3. EXTENT OF SURFACE AND RATE OF EVAPORATION.—Place four tablespoonfuls of water in a cup and the same amount in a plate. Set the cup and plate side by side in a safe place.

Observe every hour and draw a conclusion regarding the effect of the extent of surface exposed on the rate of evaporation.

FACTOR 4. HUMIDITY AND RATE OF EVAPORATION.—Select two places, one damp and the other dry, and of about the same temperature and air currents. Place in each of the similar cups four tablespoonfuls of water. Place a cup in each of the places selected.

Observe after 12 or 20 hours. Does the amount of moisture already in the air hinder or aid evaporation? Does water evaporate more or less rapidly in moist (humid) or dry air?

Draw a conclusion concerning the effect of humidity on the rate of evaporation.

FACTOR 5. DIFFERENT LIQUIDS AND THE RATE OF EVAPORATION.—Place four teaspoonfuls of water in one cup and four teaspoonfuls of gasoline or alcohol in another similar cup. *Gasoline must not be allowed to evaporate in a closed room or where there are flames.*

Observe every hour and draw a conclusion concerning the effect of the nature of the liquid on the rate of evaporation.

EVAPORATION AND TEMPERATURE

Object.—To observe the temperature effects produced by an evaporating liquid.

APPARATUS.—Thermometer. Drinking glass or cup.

MATERIALS.—Small piece of cloth. Thread. Water. Alcohol or gasoline. If convenient, other liquids, such as carbon tetrachloride, ether, and chloroform, may be given to pupils or demonstrated by the teacher. *Room should be open and well ventilated. No flames.*

PROCEDURE AND OBSERVATION.—Pour a few drops of gasoline or alcohol upon the back of the hand. What is the effect? Repeat and hasten the rate of evaporation by fanning or blowing. Is the effect more noticeable?

Wrap a strip of cloth once or twice about the bulb of a thermometer and tie with a thread. Record the temperature. Using a piece of paper, fan the bulb for a minute or so. Is there any change of temperature?

Place the wrapped bulb in a glass of water and record the temperature of the water. Remove the thermometer from the water and while holding it quietly in the air for a minute or so observe whether the temperature

rises or falls. Fan the wet bulb for several minutes, recording the temperature from time to time. Does the temperature rise or fall? Record your conclusion regarding the effect of evaporation upon temperature. Why do we sprinkle porches, sidewalks, and pavements during summer months?

PLANTS AND WATER VAPOR. (DEMONSTRATION FOR A PUPIL OR GROUP OF PUPILS)

Object.—To determine whether the leafy portion of a plant gives or receives water vapor from the air.

Apparatus.—Glass bell jar resting on a large plate or piece of glass.

Materials.—Potted plant. Large sheet of oil paper or oil cloth. Twine.

Procedure.—Moisten the earth within the flower pot and allow it to drain thoroughly. Completely cover the pot and the earth with the oil paper wrapping closely about the base of the plant. Set the potted plant on the glass pane and cover with the bell-jar. Place all in or near a window so as to be exposed to the light, and observe after 24 hours.

Observation.—Do you notice a film of water on the inner surface of the bell jar? Whence came this moisture? Do the leafy portions of a plant receive or give moisture to the air? Record your conclusions.

CONDENSATION. DEW. FROST

Object.—To make a study of the conditions favorable for the condensation of the water vapor of the air.

Apparatus.—A polished can or drinking glass. Thermometer. Wooden stirring rod.

Materials.—Water. Chipped ice. Salt.

Procedure and Observations.—(*a*) Dew. Fill the polished can or drinking glass one-half full of water and record its temperature. Add pieces of chipped ice and stir with the wooden rod. Observe carefully for any changes in the appearance of the outside of the can. If no changes are observed continue the addition of ice and stir until a change is noted. Record temperature. Whence came the film of water vapor? Does the film of water in any way represent how dew is formed? Explain.

(*b*) Frost.—Fill the can one-half full with crushed ice and record the temperature. Observe the appearance of the outer surface of the can. Does the moisture collect very rapidly? What takes place when a body of air is greatly cooled? State the effects of temperature on the capacity of the air to hold moisture. Add a small layer of salt, and stir the mixture with the stirring rod. What are the changes in the appearance of the outer surface? Does the frozen layer of water in any way represent how frost is made? Record briefly the conditions necessary for the formation of frost. When and why is it possible for one to "see his breath?"

When and why does mist form on a person's eye glasses, as he comes in or goes out of doors?

CLOUDS AND FOG. (HOME PREPARATION)

Object.—To make a study of the conditions that are (*a*) favorable and (*b*) unfavorable for the formation of clouds and fog.

APPARATUS.—Teakettle and gas range.

MATERIALS.—Water and gas.

PROCEDURE AND OBSERVATIONS.—Put some water in the kettle and boil. Turn the spout of the kettle so that the escaping steam is directed into the room.

Does the cloud form right at the mouth of the spout or at a distance of an inch or so from the mouth of the spout?

Why do engineers refer to the invisible portion between the spout and the cloud as *live steam?*

Is the air of the room colder or warmer than the escaping live steam? Is condensation taking place? Is the cloud made up of very fine particles of water?

As the cloud pushes out into the dry air of the room, does it again disappear? Are the little particles of water turning into invisible water vapor—that is, are the several little particles of water evaporating?

Turn the teakettle about so that the escaping steam passes over the flame arising from a nearby burner. Does a cloud form? Explain.

Has dry hot air a great capacity for water vapor? Give your reasons.

Has cold air a great capacity for water vapor? Give your reasons.

Explain what happens when warm air laden with moisture comes in contact with cold air.

Explain what happens when hot dry air comes in contact with a fog or a cloud.

Why do morning fogs disappear as the noon period approaches?

Why do fogs often develop during the night?

MEASURING MOISTURE

Object.—To learn the wet and dry bulb thermometer method for measuring the moisture (relative humidity) of the air.

APPARATUS.—A thermometer.

MATERIALS.—Water. Small piece of cloth. Thread.

PROCEDURE AND OBSERVATIONS.—Record the temperature of the room. Call this *the dry bulb reading.*

Place from one to two layers of cloth about the bulb of the thermometer and tie with thread. Moisten the cloth about the bulb with water that is about the temperature of the room. Hang the thermometer on a convenient support. Fan for three or four minutes. Quickly record the temperature, and fan again for two or three minutes and again record the temperature. Continue fanning until the temperature ceases to fall. Call the lowest temperature recorded *the wet bulb reading.*

What is the difference in the wet and dry bulb readings?

What causes the wet bulb to read lower than the dry bulb?

If the air in the room were saturated with water vapor would there have been any difference in the readings of the wet and dry bulbs?

If the air in the room were very hot and dry would there have been a greater difference in the two readings? Why?

Do small differences in the two readings signify that the air contains considerable moisture? Explain.

Do large differences in the two readings signify that the air is lacking greatly in moisture? Explain.

Humidity refers to moisture in the air. If the air is saturated, it has a *humidity* of 100%. If the air is only one half saturated, it has a *relative humidity* of 50%—that is, relative humidity is the amount of moisture actually present in the air compared to that which would be present if the air were saturated.

Find the "Relative Humidity Tables" printed in this chapter.

(*a*) Find the column of dry bulb readings.

(*b*) Find the column of "Differences in Degrees between Wet and Dry Bulb Thermometers" and locate the number that corresponds to the differences between your dry and wet bulb readings. Place your finger on the number.

(*c*) Run your finger down the column until you come opposite the number equal to your dry bulb reading. What number stands at the intersection of the two cross lines? This number represents the Relative Humidity or the per cent of saturation of the air.

Example: If the dry bulb reads 68°F. and the difference between the dry and wet bulb is 9, the relative humidity is 58%, that is, the air is 58% saturated.

Repeat the experiment out of doors and compare the relative humidity in doors with that out of doors.

Repeat the experiment with a wet and dry bulb thermometer.

If possible have the instructor show you how to operate a sling psychrometer. Repeat the experiment.

Water Vapor, an Invisible Form of Water.—As small children we often wondered about the rain, the mists, the snow, and the hail that fell at various times from the passing clouds and storms. Yet it is quite probable that when the days were clear and full of sunshine, it never occurred to us that water in the form of an invisible vapor was everywhere present in the air about us. However, a moment's reflection would have proved to our satisfaction that the invisible water vapor was there, for damp cloths hanging in the air became dry, moisture on the pavements disappeared, the pools of water passed

away, and exposed vessels of water became empty or less full of water. What became of all of these supplies of water? In explaining such phenomena we are quite in the habit of saying "the water has evaporated"—that is, we mean that water has changed from a liquid state to a vapor state and escaped into the air. This continual passing of invisible water vapor into the air leads us to conclude that the air must contain at all times a greater or less quantity of water vapor. Again, on clear warm days, containers of ice and cold water invariably become covered on their outside surfaces with a heavy layer of water which has been condensed from the nearby layer of air. From these and many similar observations there is but one conclusion, which is that *the air contains at all times greater or smaller quantities of an invisible form of water called water vapor.*

Factors Affecting Evaporation.—Common observation teaches us that damp clothes become dry more quickly in a warm place than a cold one, that damp clothes become dry under a hot flatiron and not under a cold one, and that sidewalks dry more readily in the sun than in the shade, and thus we conclude that *heat is a factor that hastens the rate of evaporation.*

Another factor that hastens the process of evaporation is a current of air passing over the evaporating liquid. Muddy roads and wet fields are thoroughly dried in a short time by a strong summer breeze or a light wind. However, if the air is still and laden with moisture, damp clothes and similar articles hung out to dry do so very slowly. Moisture already in the air retards evaporation, and indeed, on very damp and quiet days evaporation may not take place at all. Thus an *air current is a factor that hastens the rate of evaporation, while the water vapor already in the air retards the rate of evaporation.*

Again, when water or other liquid is allowed to stand in vessels with wide openings, we find that it evaporates more rapidly than when exposed in vessels with small or narrow openings. Thus the greater the amount of surface a liquid has exposed to the air, the more quickly it evaporates. In order to prevent highly volatile liquids like ether, gasoline, alcohol, and perfumes from evaporating while the cork is removed, they are usually stored or sold in very narrow-necked

bottles which, of course, have narrow openings that retard greatly the escape of vapors from the surface of the liquid. From these observations we discover two other factors that determine the rate of evaporation: they are *the extent of surface* and *the nature of the liquid*—that is, liquids evaporate more rapidly when there is a large surface exposed to the air, and volatile liquids like gasoline evaporate more rapidly than does water.

In summary then there are five important factors affecting the rate of evaporation: (1) the temperature of the air and the evaporating liquid; (2) the rapidity of the circulation of the air above the evaporating liquid; (3) the amount of moisture already in the air; (4) the extent of the surface of the liquid exposed; and (5) the nature of the evaporating liquid.

The Temperature of the Air Regulates Its Capacity for Moisture.—Since water evaporates more readily when exposed to warm air than when exposed to cold, we are led to conclude that warm air has a greater capacity for water vapor than cold. This conclusion is quite correct, for it has been found that a cubic foot of air at 32°F. holds 2.113 grains of water vapor, a cubic foot of air at 50°F. holds 4.076 grains of water vapor, and a cubic foot of air at 70°F. holds 7.980 grains. Now this relationship of temperature to the capacity of the air for receiving and holding moisture is one of its most interesting and important characteristics. For when we take a cubic foot of air at 70°F. which is saturated with 7.98 grains of water vapor, and cool it down to 50°F., we find that 3.9 grains of water vapor are given up in the form of dew, fog, mist, or rain. When we cool the cubic foot of saturated air down to 32°F., still more water vapor condenses, until the air contains only 2.113 grains of water vapor. This property of the air that requires it to drop its excess moisture when cooled or enables it to pick up moisture when it is warmed is a cause that produces many effects and results. For example, cold winds on becoming warm gather up the moisture of the earth over which they pass, while warm and moisture laden winds give up their moisture when sufficiently cooled. Such winds determine whether the country over which they continually pass shall be an arid and desert

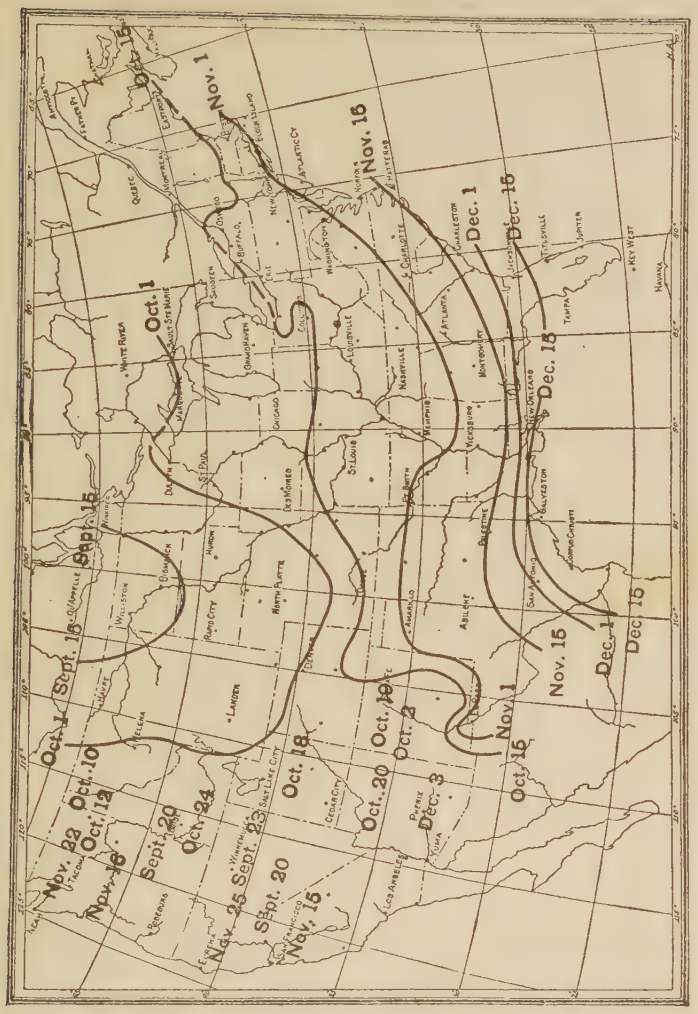


FIG. 81.—Chart showing average date of first killing frost in autumn. (*U. S. Weather Bureau.*)

waste or a place of humidity and vegetation. In short, the temperature changes of the air determine whether evaporation of water or condensation of water vapor shall take place.

Evaporation a Cooling Process.—Everyday experience has taught us to cool hot porches, pavements, and roadways by sprinkling them with water. This is so, because water changing to the invisible form of water vapor requires heat. This required heat is taken from the hot objects upon which the water is sprinkled or from the air into which it evaporates. This heat is stored away in the water vapor as insensible heat—that is, heat which we cannot feel. Water vapor cannot exist without this store of heat, and so long as water exists in the form of vapor it must have this hidden supply of heat.

Condensation a Warming Process. Dew. Frost.—However, when a layer of air laden with water vapor is in contact with any cold object that is capable of taking up heat, the water vapor is robbed of its store. On losing its heat the water vapor can no longer exist as vapor, and so condenses and appears on the surface of the object as dew or films of water.

However, every warm layer of air may not give up moisture to cold objects with which it comes in contact. It may be that the warm air is not saturated with water vapor. In such a case the cold body upon which it rests must cool the layer of air down to and somewhat below a temperature at which the air would be saturated before any moisture can be deposited. That is, if a cubic foot of air at 70°F. contained only 4.076 grains of water vapor, the air would have to be cooled below 50°F. before it deposited any of its water vapor as dew. When any body of air is cooled to a temperature at which it is saturated, it is said to be cooled to its *saturation point*, or *dew-point*. Consequently when a cold body fails to lower the temperature of a layer of air to its saturation or dew-point, no water vapor is deposited as dew. When the dew-point falls below 32°F., frost results in the place of dew.

The Formation of Fog, Clouds, Rain, and Snow.—When a deep layer of air resting on the earth's surface is cooled below its saturation or dew-point, condensation takes place not only on the objects on the surface of the earth but also on the many

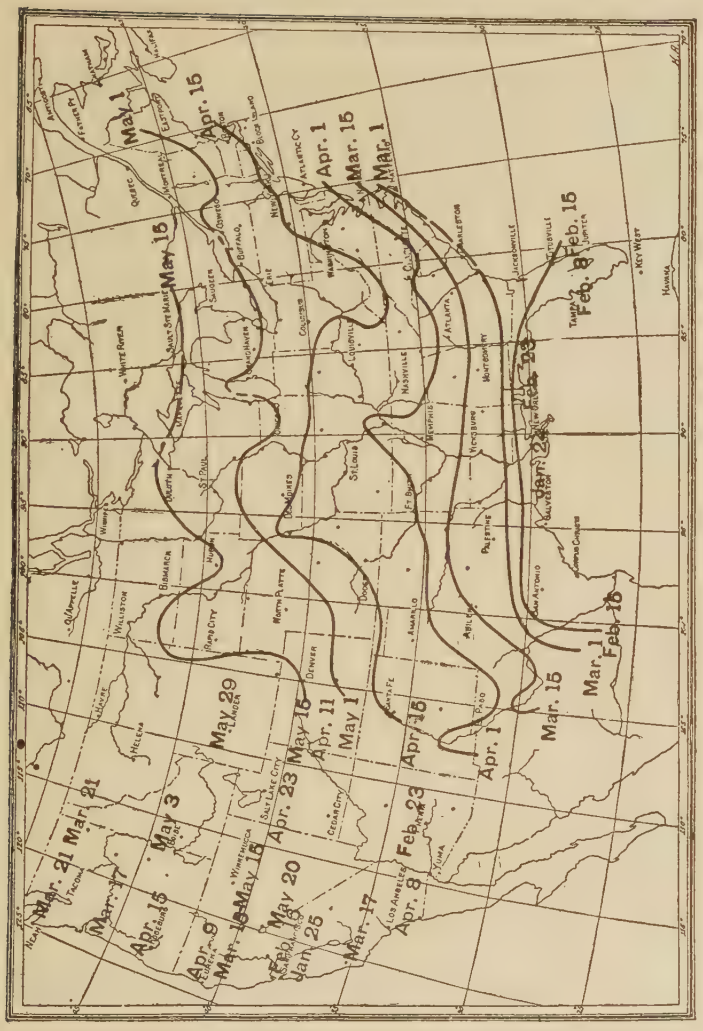


FIG. 82.—Chart showing average date of last killing frost in spring. (*U. S. Weather Bureau.*)

dust particles floating in the body of air. Each and every tiny particle of dust is surrounded by a very fine layer of water, and thus a *fog* or *mist* is observed. However, when the cooling of the air layers takes place at some distance above the earth's surface, the excessive moisture immediately condenses about the floating dust particles, and the result is a *cloud*. If the cooling is sufficient to free a considerable quantity of moisture, the drops become too large to remain suspended in the air and consequently fall as *rain*. It often happens that drops of rain on their way toward the earth pass through layers of air below freezing point, and the result is pellets of solid ice about the size of rain drops. These pellets of ice are usually referred to as *sleet*. If condensation begins at a temperature below freezing point, the condensing moisture forms crystals which we recognize as *snowflakes*.

Clouds and Their Forms.—One of the best ways to understand the conditions under which clouds appear and disappear is to watch the "steam" clouds that issue from the spout of a teakettle in which the water is made to boil. At first the steam particles are invisible and exceedingly hot. However, the stream of steam particles is soon chilled by the cool air of the room, and a dense cloud composed of water particles is soon formed. As the cloud of water particles arises and drifts out into the dry air of the room, the water particles are quickly evaporated to invisible water vapor, and hence the cloud disappears. Much in the same way, clouds evaporate and condense again in the air. Every cloud that we observe is either growing larger or dissolving away into the air. Clouds never remain the same size or shape, for the reason that the temperature and quantities of moisture in the bodies of air through which they travel are continually changing. Warm dry currents of air mixing with colder currents carrying clouds warm up the colder currents and evaporate the clouds. Warm moist currents on entering cold currents of air form clouds, or if clouds are already there, they grow larger.

The forms and appearance of clouds are many, and it is, indeed, often difficult to decide with certainty on the class to which any cloud may belong. *The International Classification*

recognizes and describes ten forms of which only the principal ones are here set forth. The *cirrus* is a delicate and fibrous cloud taking the form of long white plumes. The cirrus cloud is the highest of all cloud forms, its altitude ranging

FIG. 83.—Cirrus (the detached portions) and cirro-stratus. (*U. S. Weather Bureau.*)

from five to six miles. The *nimbus* is known as the rain cloud and lies at an average altitude of a mile. The *nimbus* from which rain or snow is frequently falling is a dark heavy layer of clouds, without shape and with ragged edges. The *cumulus*

or *wool-pack clouds* are thick dome-shaped clouds which appear to be climbing to higher altitudes. The base of a large cumulus usually appears as a horizontal line. Opposite the sun the cumulus appears brilliant white, while on the same side as the sun it appears dark with thin and silvery white edges.

FIG. 84.—Cirro-cumulus, with tufted cirrus. (*U. S. Weather Bureau.*)

The cumulus cloud appears in combination with other clouds, the chief of which are known as *cirro-cumulus* and *cumulo-nimbus*. The cirro-cumulus flies at an altitude of from two to three miles and is composed of small masses of white flaky clouds that pass without casting shadows or that cast very light shadows.

At times these clouds pass in groups or follow each other in irregular and broken lines. The *cumulo-nimbus* is known as the thunder or shower cloud. It is a heavy mountain-like cloud that has false cirrus clouds moving above its head and nimbus-like clouds floating along underneath. The cumulo-nimbus is generally accompanied with rain or snow and sometimes with

FIG. 85.—Cumulus.

hail. The *stratus* is the lowest cloud of all and is composed of horizontal sheets of rising fog.

Oceans, an Important Source of Water Vapor.– Since three quarters of the earth's surface is made up of large oceans, the greatest supply of moisture comes from these sources. The crops of the world depend largely upon the moisture that is wafted thither by the winds whose supply of water vapor is gathered while traversing the great expanses of the oceans.

FIG. 86.—Cumulo-nimbus. The characteristic appearance of an approaching thunder-storm.

FIG. 87.—Strato-cumulus.

Indeed, the millions of bushels of wheat that are produced throughout the great central portion of the United States, Canada, and all of Europe are made possible by means of water from the Pacific and Atlantic oceans that are 1000 to 2000 miles distant. The moisture that is evaporated from the lands, including their lakes and river systems, is quite insufficient. Indeed, if every lake in the world were completely evaporated, the supply would only be equivalent to about one sixteenth of the total annual rainfall received by the lands of the earth. Hence, if the plant and animal life depended upon the moisture evaporated from the rivers and lakes, the great continents would soon become desert wastes in which life would be difficult if not impossible.

Plants Transpire Water Vapor.—During and after all rainfall some water runs off the ground without sinking into the soil, some evaporates back into the air, and some sinks below the level of the surface and saturates the under layers of earth. The portion of rainfall that sinks below the surface is known as soil water and is the source of water supply so necessary to all plant life. Again, a plant finds a portion of its food materials dissolved in the soil water. Hence, it becomes necessary for the plant to gather up the soil waters, which it does by means of innumerable root hairs, roots, and rootlets that spread throughout the soil. Since the leaves of a plant are the chief transpiring (water-losing) organs of the plant, there is, during a healthy growing condition, a continuous stream (transpiring stream) of water from the roots to the leaves.

The amount of water vapor that is transpired by a plant is surprisingly large. During its life time a sunflower plant may give off enough water vapor to produce seventeen gallons of water; a corn plant from three and one-half to four and one-half gallons. In the wheat regions of the western United States, the water given off by a field of wheat during its period of growth and development would cover the field to a depth of about five inches, which is practically one-fourth of the annual rainfall for the western wheat regions. That is, the wheat crop collects one-fourth of the entire rainfall that is received upon the fields in which it grows, and transpires it back to the air. Con-

sequently, good crop yields are dependent upon abundant rain well distributed throughout the growing season of the crop.

Again, the great quantities of water vapor transpired by the vegetation of the earth serve as a sort of balance that makes living conditions more suitable and tolerable for all forms of life. For the moisture given off so abundantly by the plant during the hot hours of the day takes up heat during the process of evaporation, which heat is given back again during the cooling period of the night when condensation of water may take place to form dew or clouds or even local showers of rain. Thus the heat of the day is distributed throughout the night, and the moisture which falls as rain is made to serve the plant anew as soil water.

Means of Determining the Amount of Water Vapor Present in the Air. Relative Humidity.—By the term *humidity* we refer to the amount of moisture in the air; and by *relative humidity* to the amount actually in the air compared to that which should be there were the air saturated. Relative humidity is usually expressed in per cent. If a cubic foot of air containing only 3 grains of water requires 10 grains to saturate it at the given temperature, the air is only $\frac{3}{10}$ or 30% saturated—that is, the air has a relative humidity of 30%.

If we take two thermometers that under similar conditions register the same temperatures and about the bulb of one secure a layer of cloth which has been moistened with water, we shall find after several minutes that the thermometer with the wetted bulb registers a temperature lower than that with the dry bulb. This, of course, is due to the evaporation of the water from the cloth about the wetted bulb. Had no evaporation taken place, no cooling effects could have been produced, and consequently the two thermometers would have read the same. Had very little evaporation taken place, the difference registered would likewise have been very little. However, had a great deal of evaporation taken place on the surface of the wet bulb, the cooling effects would also have been considerable. Hence, the difference in the temperatures registered by the two thermometers depends directly upon the amount of evaporation that takes place. The amount of evaporation

that takes place is governed by the amount of moisture already in the air; when the air is dry there will be considerable difference in the two thermometer readings, and when the air is nearly saturated there will be small difference in the readings.

The above facts are used as the basis of a method frequently employed for determining the amount of moisture that is present in the air. Two thermometers with provisions for keeping the bulb of one wet are mounted upon a common board as shown in the Fig. 88. In order to make an accurate determination it is necessary to fan or set the air in motion about the thermometers for some five or six minutes before

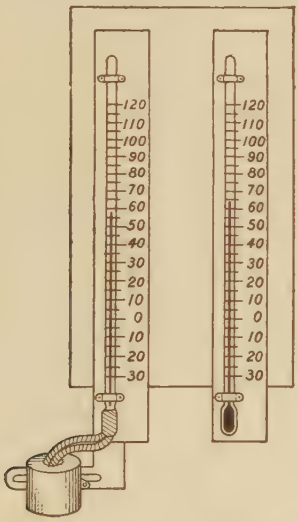


FIG. 88.—Wet and dry bulb hygrometer. (*From Tower, Smith, Turton, and Cope's Physics.*)

they are read. The relative humidity is found by making use of a set of tables that have been worked out by the Weather Bureau Service. These tables express the relative humidity in terms of per cent.

When the thermometers have been read, their differences are taken. This number which represents the difference of the two readings is found in the tables in the topmost row of numbers under the head of "Difference in Degrees between

Wet and Dry Bulb Thermometers." Placing your finger on the number, run it down the column until it is directly opposite the dry bulb reading. The number standing at the intersection is the relative humidity of the air expressed in per cent.

For example: The dry bulb registers 68°F., and the wet bulb registers 55°F. The difference between the two readings is 13°F. At the intersection of the two columns running from 13 and 68 we find the number 42—that is, 42% is the relative humidity of the air.

HUMIDITY TABLE

	Difference between dry and wet thermometers																				
Degrees.....	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Reading of dry-bulb thermometer	Per cent humidity																					
65	95	90	85	80	75	70	65	61	56	52	48	44	39	35	31	28	24	20	17	13	10	6
66	95	90	85	80	75	71	66	61	57	53	49	45	40	36	32	29	25	22	18	14	11	8
67	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	30	26	23	19	16	12	9
68	95	90	85	81	76	71	67	63	58	54	50	46	42	38	34	31	27	24	20	17	14	10
69	95	90	86	81	76	72	67	63	59	55	51	47	43	39	35	32	28	25	22	18	15	12
70	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36	33	29	26	23	19	16	13
71	95	91	86	81	77	72	68	64	60	56	52	48	45	41	37	34	30	27	24	20	17	14
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38	35	31	28	24	22	18	15
73	95	91	86	82	78	73	69	65	61	57	53	50	46	42	39	35	32	29	25	22	19	16
74	95	91	86	82	78	74	70	66	62	58	54	50	47	43	40	36	33	30	26	23	20	18
75	95	91	87	82	78	74	70	66	62	58	55	51	47	44	40	37	34	31	27	24	21	19
76	95	91	87	82	78	74	70	66	63	59	55	52	48	45	41	38	35	31	28	25	22	20
77	95	91	87	83	78	74	71	67	63	59	56	52	49	45	42	39	35	32	29	26	23	20
78	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43	39	36	33	30	27	24	21
79	96	91	87	83	79	75	71	68	64	60	57	53	50	47	43	40	37	34	31	28	25	22

Problems.—Learn to use the above table by locating the relative humidity readings for the following suggested readings.

Dry Bulb Reading, Degrees Fahrenheit	Wet Bulb Reading, Degrees Fahrenheit	Difference, Degrees Fahrenheit	Relative Humidity, Per Cent
72	64	8	65
70	62	?	?
70	56	?	?
67	50	?	?
80	63	?	?

If on a given day in winter we should determine the relative humidity out of doors and then in doors, it is more than probable that we should find the air out of doors of high humidity, and that in doors, low. Why is this? The cold air out of doors has little capacity for moisture, but when heated and passed into our living rooms it has a high capacity for moisture on account of the high temperature to which it has been heated. This lack of moisture in the heated air of our living rooms not only causes discomfort but accounts for a large percentage of catarrh, colds, and other diseases of the mucous membrane lining the nose and throat. Proper amounts of water vapor should be added to heated air before it is admitted to the living rooms. Too much moisture prevents evaporation from taking place from the surface of the body, and so we feel oppressed. Consequently the moisture must be so regulated as to result in the greatest comfort. Relative humidities around 58% at a temperature of 68°F. are recommended for living rooms of homes, study halls, and similar places where there is no great bodily activity. Further study of proper humidity and its relation to health will be taken up in a future chapter.

Projects

1. To make a study of an iceless refrigerator in order to be able to construct such a piece of apparatus for the preservation of foods at a summer camp.

Suggestion.—Write to the U. S. Dept. of Agriculture for Food Thrift Series #4.

2. To make a wet and dry bulb hygrometer, to make a study of the conditions of humidity in the living rooms of the home, and to bring about conditions for proper humidity.

Suggestion.—Write to Taylor Instrument Companies, Rochester, N. Y., for "The Tycos Hygrometer Book."

3. To write a theme on "Clouds and Cloud Forms." Illustrate the paper with magazine pictures, photographs, or water color drawings of clouds. Quote descriptions concerning clouds by recognized writers and poets.

CHAPTER X

THE WEATHER AND CLIMATE ABOUT OUR HOMES

Object.—To make a study of the general conditions of weather and climate that take place from day to day and from season to season in order to adjust the mode of living in such a region to the best advantage.

Weather and Climatic Conditions Affect our Health and Energy.—When we compare the habits and activities of people living in the tropical zone with those in the temperate zones, we find the one inclined to be very inactive and unprogressive and the other active and progressive. The vigor of the people of the temperate zones is largely due to climatic influences. In the temperate zones the weather varies from day to day, and the climatic influences vary greatly from season to season. These variable conditions of weather and climate seem to arouse and stimulate man to put forth his best mental effort and physical exertion. The largest cities of the world, the great industries, the ideals of government, the centers of learning and art are all located in or spring from the regions of variable weather and climate.

In the temperate climate man must sow and cultivate in the spring in order that he may harvest and build and store in the autumn and thus make preparation to live through the winter. In the winter he must design and plan and make ready for the coming spring in order to take advantage of every opportunity that presents itself in the coming season. Just as this is true of farming, it is also true of every other occupation. The business man must lay in stocks and stores in proper season. The manufacturer gathers his raw materials in the season of greatest supply and arranges to have his manufactured articles on the market during the season of greatest demand. The seasonal changes regulate and determine these activities in a greater or less degree.

From what has been said it may well be claimed that conditions of heat and cold, drought and moisture, sunshine and clouds, winds and storms are important factors that are in some way related to human life and human activities. Too much sunshine and heat in the torrid zones and too little in the polar, too much humidity in the valley of the Amazon river and too little in the Sahara desert are extreme climatic conditions that make the inhabitants of these regions inefficient and dull. Likewise the extreme heat of summer and the extreme cold of winter are the unfavorable periods for the greatest amount of physical and mental exertion in the temperate climates. In the midsummer season the peoples' health and energy are probably no better than in the midwinter season. True, the diseases that afflict people at each of these periods are quite different. In the summer season the doctors and health officers are busy with health problems peculiar to the season, "hot waves" of summer producing quite as much human disaster and inefficiency as the "cold waves" of winter. Proper food, proper clothing, proper housing, proper exercise and habits of life and work will do much to combat the extremes of weather and climate. However, to use these factors to their best advantage a knowledge of the climatic and the weather conditions about us are desirable and fundamental.

THE BAROMETER AND WEATHER

(Directions and suggestions given in Chapter VIII. Complete the experiment at this time. Your answers should be based entirely on what you have recorded in your table.)

THE WEATHER MAP

Object.—To learn to read the weather map.

MATERIALS.—Daily weather map. (If possible make arrangements with the Weather Bureau Station of the region in which the school is located for enough copies to give each child a daily map for five days. Otherwise post the daily maps side by side on a large bulletin board in order that the daily map may be compared and contrasted with those of preceding days.)

PROCEDURE AND OBSERVATION.—1. Find the date, time, and place of issue of the weather map.

2. Find the isobars. Read the numbers on several isobars. What do these numbers mean? What instrument determines these numbers?

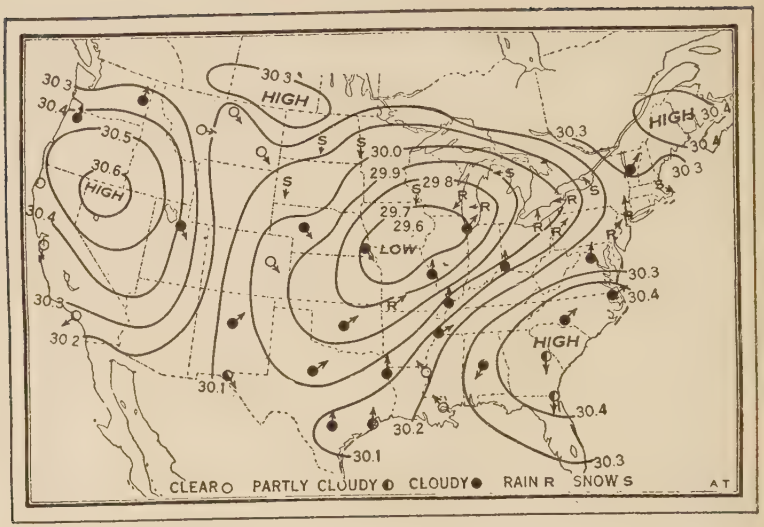


FIG. 89.—A typical winter storm central over southern Iowa, December 15, 1893. The lines pass through points of equal pressure. The arrows fly with the wind and show that it blows spirally inward toward areas of low pressure, and outward from areas of high pressure. (*U. S. Weather Bureau.*)

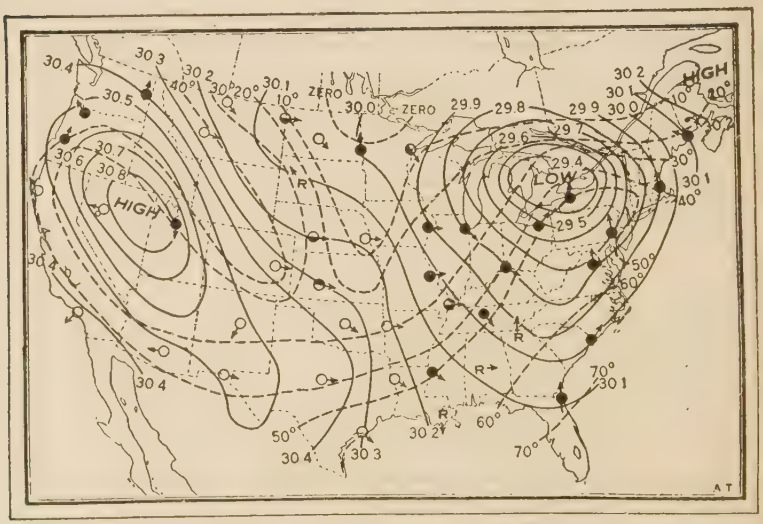


FIG. 90.—Twenty-four hours later than Fig. 89, December 16, 1893. The storm center has moved to the lower lake region. The dotted temperature lines are shown on this map and indicate the influence of wind direction on the temperature. (*U. S. Weather Bureau.*)

Find the "highs" and "lows" on today's map. How do their locations compare with the location of the "highs" and "lows" on yesterday's map and that of the day before yesterday? Place the three maps, in their order of dates, on the table before you. Are the "highs" moving generally toward the east or toward the west? How do you know?

3. Find the isotherms on each of the three maps. Where are the lowest temperatures, in the north or in the south of the United States?

4. How is the direction of the wind indicated on the weather map? On the eastern side of a low what is the direction of the wind? On the western side of a low what is the direction of the wind? Find the direction of the wind on the eastern and western side of a high. Does the wind travel clockwise or counter-clockwise about a low? On today's map which way is the wind blowing in Chicago? On yesterday's map which way was the wind blowing? On the day before yesterday which way was the wind blowing? Can you explain the causes that produced these changes in the direction of the wind?

5. When a high approaches your home what way is the wind blowing? As the high pressure leaves the region of your home which way does the wind blow?

6. How are the weather characteristics, *clear*, *cloudy*, *rain*, and *snow*, indicated on the weather map?

7. What does the shaded portion mean?

8. Read the *forecast* for your state. Is a *general forecast* given for the whole of the United States? Compare the forecast with the conditions indicated on the map.

9. Is there any advice to shippers? Read it. Do you think it of value? Explain.

10. Of what value is the Weather Bureau Service to railroads, to shippers, to fruit growers, and to steamship lines?

Weather and Climate. Environment.—At the beginning of this chapter it was pointed out that conditions of weather and climate have a great deal to do with the general health and progressiveness of a people in whatever region they may happen to live. No matter how we live or what we do we are brought into contact with the forces and influences that surround us. These forces and influences that affect us so greatly have to do with our supplies of heat, light, water, air, and food. However, there are few regions on the surface of the earth where all the factors and influences composing the environment are at all times favorable and without great variations. The variations may be daily or annual, may be irregular and sudden, or may be gradual and extending through long periods of time.

The conditions of the atmosphere that exist at some particular place at a particular time are referred to as the *weather*—that is, by *weather* we mean the temperature, the wind, the percentage of sunshine, and the amount of precipitation upon a particular day. By *climate* we refer to the average atmospheric conditions existing in a certain region for a period of time. The climate of a given place may be referred to as warm during the summer season and cold during the winter season, or dry in the summer months and wet in the winter months. The climate tells us little or nothing about the weather conditions that exist from time to time, for the days in the summer season may be extremely hot and dry while those in the winter season

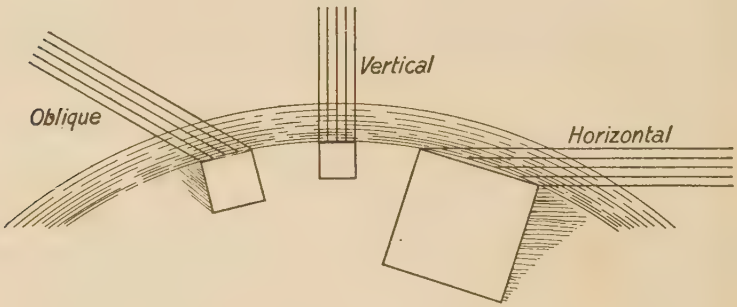


FIG. 91.—Relation of solar heating to altitude of the sun. An illustration of the teaching that the more nearly vertical the sun's rays are, the more restricted is the area heated by a solar beam of any given cross-section, and the more intense the heating effect. (*From Brownell's General Science.*)

may be extremely cold. When planning to spend a vacation period, or to buy a farm, or to locate a business in some region, we should not only inquire regarding the general climatic conditions, but investigate the climatic conditions that exist generally during the extreme seasons of summer and winter. This sort of information is obtainable from the U. S. Weather Bureau in the Dept. of Agriculture at Washington, D. C.

Winds and Their Causes.—Since the earth receives its heat from the sun, the sun is manifestly the ruler of temperatures on the earth's surface. The changes of temperature from day to night, from summer to winter, from the equator to the poles, all follow the changes in the intensity of sunshine. These changes are brought about by the earth's rotation on an

inclined axis while it is coursing its way on a well defined orbit about the sun. Since only one-half of the earth's surface can be brought into the sunlight at any one time, we find the parts in shadow cooling while the parts in sunshine are warming. The earth's atmosphere, being transparent to the radiant heat of the sun, receives little heat from the sun's rays that pass through. However, when the rays strike the surface of the earth, they are more or less absorbed and thus heating effects are produced.

Since bodies of water have greater capacities for absorbing heat than land bodies, unequal temperatures are the result.

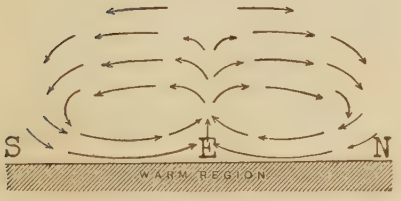


FIG. 92.

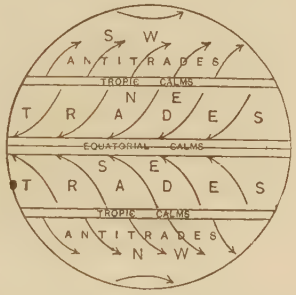


FIG. 93.

FIG. 92.—Cold winds from the north (N) and south (S) become warmed as they pass toward the equator (E). Rising to higher altitudes the winds flow away from the equator toward the north and the south.

FIG. 93.—The winds do not flow from the north and the south for the reason that the rotation of the earth deflects them. Hence winds from the northeast and southeast flow into the equatorial region. Flowing out of the region of tropic calms are the westerlies or antitrade winds.

Again, bodies of land not only heat up more rapidly but cool off more rapidly than do bodies of water. Hence, layers of air resting upon the surface of land bodies are heated or cooled more rapidly than those resting upon the surface of lakes, seas, and oceans. During the day the temperature of the land becomes higher than that of the sea. Consequently, the air over the land expands, becomes lighter, and is driven backward and upward by the colder and denser air from the ocean. At night the land cools more quickly than does the neighboring waters, and hence the cold and denser air of the land rushes seaward to displace the warmer layers of air. Currents of air

rushing from the sea to the land are called *sea breezes*, while the reverse are known as *land breezes*.

Again, since the equatorial regions are the most heated regions of the earth, we find the large convection currents, the *trade winds*, rushing from regions of high pressure on the north and the south toward the equator, a region of low pressure, and continually forcing the warm and moist air of this region

FIG. 94.—The wind map gives the general directions for winds during the month of January. United States lies in the path of the prevailing westerlies. Observe the conditions that give rise to the formation of cyclonic storms, *C*, off the coast of British Columbia in North America.

to ascend and flow back toward the north and south as shown in Fig. 92.

The trade winds do not flow directly from the north and south toward the equator, for the reason that the rotation of the earth deflects them. Those pouring from the north appear to come from the northeast, while those from the south appear to come from the southeast. North and south of the regions of the *trade winds* we have the regions of the prevailing *westerlies*. The directions of the Trade Winds and Westerlies are so constant that they may be depended upon for driving sailboats for the purposes of commerce. The sailing vessels that arrive from Europe come by way of the "Northeast trades" and return by way of the westerlies. (Fig. 93.)

Low and High Pressures.—Cyclones and anti-cyclones. Looking on a map of the world, we find that the great expanse of

the United States lies in the path of the prevailing westerlies for the northern hemisphere. The winds on reaching our western coast are warm and laden with moisture. As the winds rise to pass over the great western highlands, they deposit on the western slopes of the mountain ranges great quantities of moisture in the form of rain or snow. Since these winds continue eastward over the United States, one would think that the Central and Eastern States would become arid wastes. As a matter of fact, we know that sufficient rain falls throughout these sections for the growth and development of abundant crops.

Furthermore, we find no very regular winds over this entire area, but on the contrary we find the winds and temperature to be quite changeable. In any particular region it may be warm and pleasant with a south wind, but on the following day a cool dry wind may blow from the northwest. After two or three days this northwest wind may give place to a clouded sky and rain brought thence by east or south winds. These periods of variable weather follow one another in close succession throughout the year.

The reason for such changeable weather throughout the United States is the great storms that move across it from west to east with more or less frequency. These storms originate in the northwest as areas of low atmospheric pressure in which the air is lighter and less dense than the air of the surrounding regions. That is, the *low pressure area* is surrounded by *high pressure areas*. When such a condition exists we find the air currents flowing from the heavier areas toward the lighter areas. Since these air currents flow toward the area of low pressure from all directions, we have winds on the south side blowing from the south, winds on the east side from the east, winds on the north side from the north, and winds on the west side from the west. While these winds are driving toward the center of the area of low pressure, they are somewhat deflected toward the right of the center and thus set up a rotary motion about the center of the low pressure areas. In the northern hemisphere this rotary motion is always opposite to that taken by the hands of a clock, and thus the motion of the winds about a low pressure

area is known as counter-clockwise. In the meantime the low pressure area covering thousands of square miles of territory has been moving eastward at the rate of several hundred miles per day. As the low pressure area advances, the air rises near the center. The rising air is cooled and its moisture condensed to clouds, or rain, or snow. Such an area of low

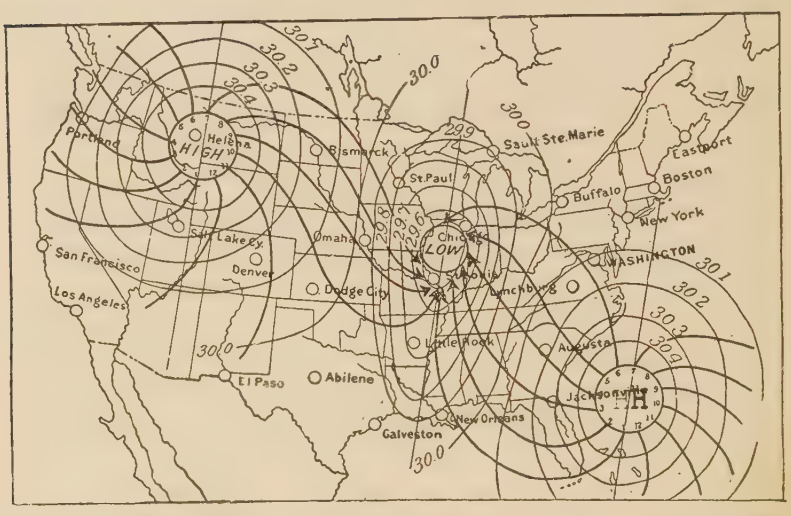


FIG. 95.—The winds from the high pressure flow toward the area of low pressure. In the map we have a condition where the cold winds from the northwest flow into the southern portion of the low while warm and moisture laden winds flow in from the south and southeast. Hence in the eastern portion of a low area, the conditions are favorable for condensation of moisture. In the western portion of a low area, cold winds are being warmed as they travel southward. Hence the conditions are favorable for evaporation of moisture and clear weather. While the winds are driving toward the center of the low, they are deflected as shown in the map. This condition of affairs causes the winds in the low area to rotate in a direction opposite to that taken by the hands of a clock. As the winds flow out from a high they take the direction of the hands of a clock. Since the winds flow inward and rotate about the central area of the low, it is known as a cyclonic storm. In the area of high pressure the winds rotate and flow away from the central area, and therefore highs are known as anticylonic storms. (*From the Popular Science Monthly, July*, 1898.)

pressure with all its movements, its clouds, and rain, is known as a *cyclonic storm area.* In every cyclonic storm there are three movements within its great body of air, i.e., (1) rotation, (2) a general movement of the whole mass in one direction, (3) ascending currents of warm air near the center.

Since the air of the high pressure areas is continually flowing into the low pressure area, the air of the high pressure is con-

tinually flowing outward from its central portion, which is being constantly supplied by a downward flow of cold air from higher altitudes. As the air flows away from the center, it rotates spirally outward, and thus high pressure areas are known as anticyclones. In an anticyclone there are three movements within its great mass of air, i.e., (1) a spreading spiral rotating clockwise, (2) a general movement of the whole mass in one direction, (3) descending currents of cold air near the center.

Cyclones Produce Variable Weather.—When a given cyclonic storm, or low pressure area, starts on its passage across the United States, warm winds from the south and east and cold winds from the north and west flow into it. As the warm winds flow northward, they warm the regions over which they pass. As the cold winds from the north flow southward, they cool the regions over which they travel. Thus on the southern and eastern side of a low we have warming effects taking place, while on the northern and western side cooling effects are taking place. Again, as the warm currents are forced to rise as they approach the central portion of the cyclonic storm, they are greatly chilled and form clouds or drop their burden of moisture as rain or snow. As the cold winds of the north are being warmed, they gather moisture instead of condensing moisture. Hence on the southern and eastern portion of a low we have warm, cloudy, and rainy weather, while on the northern and western portion we have cold and clear weather. Therefore when a low approaches, we have warm weather with south or east winds accompanied, more or less, by quantities of rain or snow. When the center of the low has passed, we have colder weather with west or north winds and a clear sky.

The passing of a cyclonic storm or low pressure area is closely and quite regularly followed by an oncoming anticyclone or high pressure area. The events and changes of weather are in a general way the reverse of those taking place in the cyclonic storm. With the advance of the anticyclone cold and clear weather is the rule. With the passing of the high pressure area warmer weather usually results, and the barometer lowers and announces a closely following low. Near their central areas anticyclones possess a gentle descending movement of air, which

spreads out over the surface of the region over which it passes. In winter this descending column of air may have an extremely low temperature and is referred to as a *cold wave.* In summer the descending air of a high pressure is cool and refreshing and serves to stimulate us to put forth greater effort.

Storm Paths.—In the above paragraph cyclones have been described as traveling storms. The central areas of these low atmospheric whirls advance along well defined tracks that are peculiar to the region of their occurrence. For the United

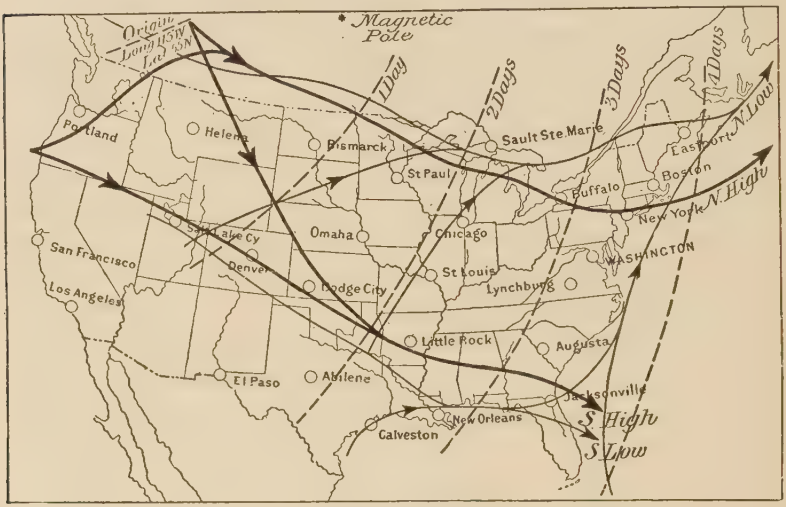


FIG. 96.—Mean tracks and average daily movement of storm paths in the United States. (*U. S. Weather Bureau.*)

States the low pressure areas that give rise to the cyclonic storms originate or come from three points of the compass and advance to the fourth point of the compass as shown in Fig. 96.

The majority of the storms that originate off the northwestern and western coast of the United States and Canada sweep the Northwestern States and Southwestern Canada, traverse the region of the Great Lakes, and then go down the valley of the St. Lawrence to the region of the North Atlantic. A great number of these storms after passing the western highlands take a more southerly direction and penetrate far into the central portion of the United States before turning to escape

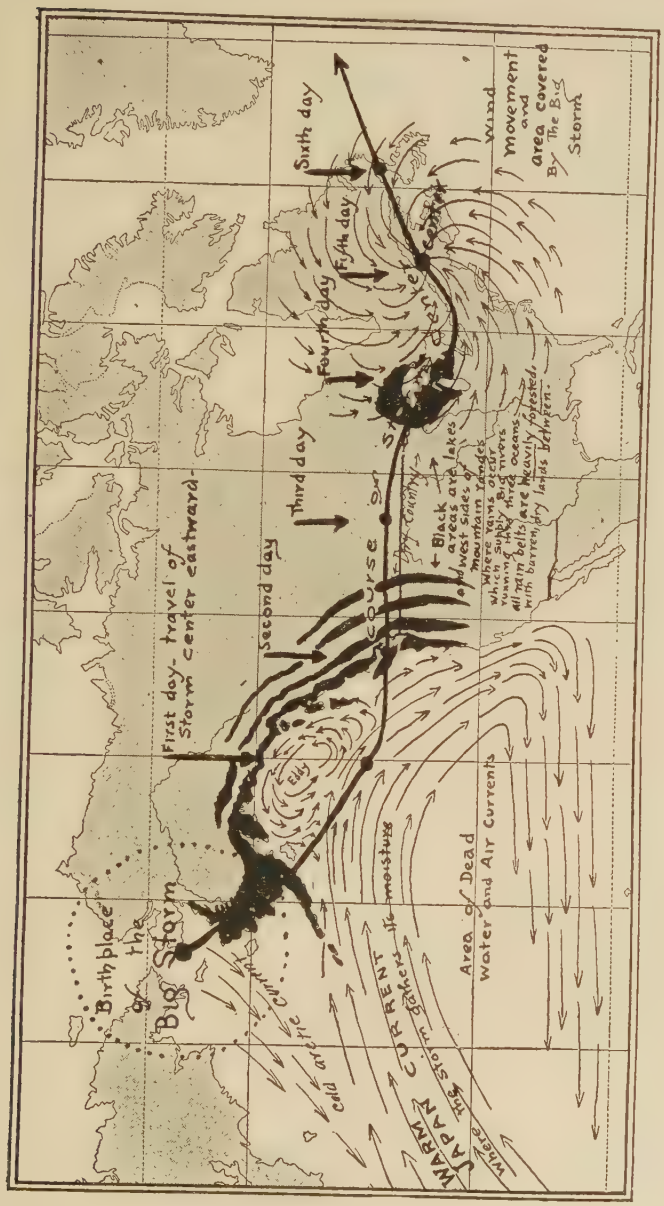


FIG. 97.—Map showing route and motion of the big storm. (*U. S. Weather Bureau.*)

by way of the North Atlantic States. The cyclonic storms that enter the southwestern corner of the United States travel a northeasterly path that leads directly to the North Atlantic States. The storms that originate off the coast of Florida go directly northward along the Atlantic Coast to the mouth of the St. Lawrence. From the foregoing we observe that all three great storm paths finally merge into one path that leads directly across the North Atlantic to Northern Europe. Thus we observe that nearly every portion of the United States is traversed more or less frequently by great cyclonic disturbances that vary the weather from day to day.

Cyclonic Storms and Human Welfare.—The sea coasts and the great interior regions of the United States are fast becoming great home regions in which mankind finds conditions favorable to the pursuit of every kind of civilized occupation. This is largely due to the fact that the United States is a region of cyclonic storms. Regions of cyclonic storms are very favorable to agriculture, because of the nice distribution of rain fall over large areas throughout the year. Moreover, regions of cyclonic storms are exceedingly conducive to human welfare. The extremes of weather from day to day arouse man to greater action. Those regions of the world that have the same average weather conditions day after day suffer from the deadening effects of monotonous weather. People who live in the tropics are more or less inactive, put forth little energy and are seldom awakened to great mental activity. In short, they are continually receiving too much sunlight and too much heat, too much moisture or too little moisture—that is, the extremes of weather exist continuously without much variation.

In the region of cyclonic storms we have hot sultry weather for a few days, during which our energies run down to a low ebb. Then follows a period of dark and rainy weather, after which follow days of cool winds and blue skies full of sunshine. Each period of weather awakens and causes us to put forth renewed energies and added determination to accomplish the tasks that confront us. Further, this variableness of weather from day to day arouses and stimulates a high degree of mental activity, and thus the people of the United States have become

renowned for their great number of worthy inventions, industrial enterprises, educational advancement, and accumulation of wealth. Hence, as individuals and as a nation our competency and high efficiency are in a degree dependable upon effects brought about by the existence of frequent cyclonic storms.

The Thunder Storm.—Since the greatest number of thunder storms occur at or shortly after the hottest hours of a spring or summer day, unequal heating effects of the earth's surface, and the overlying layers of the atmosphere have been ascribed as the causes of this kind of local storm. However, thunder storms may continue to develop after nightfall and even into the early hours of the morning, and thus unequal cooling effects of the lower layers of the atmosphere may also bring about conditions favorable to the creation of thunder storms. Furthermore, a thunder storm may develop out of a portion of a larger cyclonic storm when the winds of the latter come from regions of strongly contrasted temperatures. Thunder storms travel at a rate of twenty to fifty miles per hour, or a velocity that is somewhat greater than that of the cyclonic storms in which they occur. Since thunder storms are constantly traveling eastward, they are continually passing from the warm air of day-time into the cooler air of the night. Hence they usually increase in strength during the afternoon, weaken in the evening, and disappear before midnight after traveling a path of two to six hundred miles in length.

When a thunder storm approaches, the sky is gradually overcast, the air is warm and oppressive, flashes of lightning are seen, and distant thunder is heard. As the storm nears the neighborhood of the observer, warm currents of air rush past and directly into the storm area; indeed, the storm appears to be "coming up against the wind." As the storm comes nearer, the wind seems suddenly to reverse itself, and there is an onrush of cool air that carries leaves and bits of debris along with it. Then follows a dash of rain, the temperature falls rapidly, the barometer rises suddenly, and the darkness of the downpour is broken by vivid flashes of lightning accompanied with heavy rolls of thunder. The rainfall seldom lasts more than an hour,

FIG. 98.—The tornado. (*From Brownell's General Science.*)

FIG. 99.—The effects of a tornado. (*From Brownell's General Science.*)

unless a second storm follows in the wake of the first. Heavy downpours of rain are often referred to as *cloud bursts*.

The Tornado.—Tornadoes are local whirlwinds of great energy. They appear as funnel-shaped clouds that hang from the bottom of great masses of the thunder cloud as shown in Fig. 98. The funnel is created by a whirling mass of ascending air. The diameter of the lower end of the funnel seldom exceeds a few hundred feet, but the whirling mass of destructive winds about the funnel covers a much greater space. The violent whirling funnel advances toward the east or northeast at the rate of twenty-five to fifty miles an hour. The roar of the whirling mass is deafening, and as the tornado advances, its winds destroy everything with which they come in contact.

A single tornado may continue for half an hour or an hour and devastate a path from a mile to twenty five miles in length and less than a quarter of a mile in width.

The Weather Bureau and Weather Service.—In 1869, Professor Cleveland Abbe, with the aid of the Cincinnati Chamber of Commerce, established a weather service on a small scale for the Ohio valley. This was followed in 1870 on a more extensive scale by General Myer, Chief Signal Officer of the Army, and adopted by Congress as a national service. Professor Abbe was invited to Washington, where he took charge of the central office and was for some time the only predicting officer. On July 1, 1891, the meteorological division of the Signal Service was by an order of Congress transferred from the Army to the Agricultural Department under the title of Weather Bureau. Professor M. W. Harrington was appointed as its chief.

In order that the Weather Bureau may be of actual service, 200 branch weather stations and 250 observing stations have been established throughout the United States and Canada. Several hundred volunteer observers, also, make daily records, which they submit to the regional station or direct to the Weather Bureau at Washington. At all of the stations observations are systematically made on pressure, temperature, wind, humidity, sky, and precipitation, and this and other information is recorded. The records are translated into a cipher code. At

8:00 A.M. and 8:00 P.M., Washington time, every telegraph line is open only for the transmission of the cipher reports of the Weather Bureau. These cipher reports are received by all the main stations, where they are translated back into the original form, recorded, and charted on maps. A general forecast is at once prepared with general predictions for the several regions that make up the United States. The usual forecast is for a period of thirty-six or forty-eight hours, but it is often made for more extended periods.

The value of the Weather Bureau Service is difficult to over-estimate. When a cold wave is perceived in its early stages as an accumulation of cold air under high pressure in the regions of the northwest, its advancement eastward and southward is under constant observation. Information is sent to all the cities and places that lie in the path of the cold wave. Stock raisers in the western plains, railroad employees in charge of cattle trains, beef companies and pork packers in the central states, shippers of perishable goods, ice companies waiting to harvest ice on northern lakes, all prepare for the worst or the best that the cold wave may bring them. The janitors strengthen their fires, and insurance patrols and fire companies redouble their vigilance in anticipation of fires so often caused by over-heated furnaces and chimneys. Conflagrations in cold periods are difficult to extinguish when winter gales fan the flames and freeze the water in the water lines and the hydrants.

Tropical hurricanes hurrying across from Cuba are constantly watched, and the inhabitants of the whole southern coast are informed when danger from this source arises. The late frosts of spring and the early frosts of fall are foretold to fruit growers. Cotton planters of the south look for warnings of damp and wet weather. Hundreds of thousands of people who live in town and country seek news of the ending of a hot wave in summer by a turn to westerly winds, or the end of a drought by the advance of rains.

In addition to the Daily Weather Map the Weather Bureau publishes and distributes a Monthly Weather Review, and during the planting and growing season it sends out weather

crop bulletins that give information of interest to farmers, gardeners, and fruit growers. The Monthly Pilot Charts of the North Atlantic are issued for the Navy Department for distribution to masters of vessels. The pilot charts contain a large amount of information concerning winds, storms, ice, etc., of the North Atlantic from month to month. Coasting and fishing vessels are informed before leaving port if they are likely to meet a storm on their course, and, in extreme cases, are warned not to sail at all. Disasters on the Great Lakes have been materially diminished by warnings of coming storms. Year by year the services of the Weather Bureau become more and more extensive and of increasing importance. The more informed the people become regarding the purpose of the Weather Bureau, the more useful becomes its many branches of special service.

Climate and Factors That Determine Climate.—As stated before, climate is the average weather or atmospheric conditions that exist for a given region for a month, a season, a year, or a decade. The most important climatic elements are: first, temperature; second, various forms of moisture, such as vapor, clouds, and precipitation; third, wind, including storms. When these elements are averaged for a year, little or no information is given regarding the extremes of seasonal conditions. For when the temperatures of a hot summer season are averaged with those of a cold winter season, the temperature element for a given region may look very favorable. The better way is to express the climatic conditions of each of the seasons for a given region.

When considering the climate of any region with regard to its effects upon plant and animal life and the comfort and health of the inhabitants, we wish to know:

1. The average temperature and the extremes of temperature.
2. The average relative humidity and the extremes of relative humidity.
3. The prevailing direction and force of the winds. The nature of the land and sea breezes.
4. The rain fall and the seasons at which it is the greatest.
5. The percentage of sunshine.

6. The prevalence of fogs and dust in the air.

7. The frequency of unusual weather conditions, i.e., tornadoes, hurricanes, hailstorms, late and early freezing spells, etc.

8. Altitude and resultant air density.

However, with the exception of the southern seacoast of California, in no region of the United States do we find all the elements of climate so well proportioned as to provide an ideal climate throughout the year. The coasts and lake regions of Maine have ideal summer climates, but the winter climates are severely cold and long. The coasts of Florida are comfortable during the winter season, but on account of the high averages of temperature and relative humidity its summer climate is neither pleasant nor invigorating.

The states of Iowa, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, and all of New England lie in the pathway of most of the great cyclonic storms that pass across the United States. The inhabitants of these states are subjected to sudden and severe changes of weather. Yet within this region lives about one-half of the entire population of our nation, who possess more than one-half of the national wealth, educational institutions, and political influence. The average temperature for this section is 73° for July and 26° for January. Its relative humidity for summer is near 68%, while that of winter is about 78%. Its percentage of sunshine is from 60% in summer to 40% in winter. In many ways this region is ideal for stimulating mental effort and arousing physical exertion without much discomfort.

On account of a wide variety of climates existing throughout the United States we have greater national opportunities than perhaps any other nation of the world. The climate has fixed the cotton belts of the south, the corn belts of the central states, the wheat fields of the west and north, the subtropical fruits of Florida and California, the hardier fruits in the valleys of Washington and Oregon, on the hillsides of New York, and in the lower peninsula of Michigan.

The climate, in determining the nature of the plant life of a given region, determines the abundance and kind of animal life of the various regions. The abundance of grass and grain

lands in various regions determines the abundance of its dairy products. In the corn belts are found the hog raising enterprises. In the semi-arid lands of mountain regions are found the great flocks of sheep; and in the great grass plains, the large herds of beef cattle. And thus, of all the factors that make up our environment, climate is the most vital and far reaching, for it determines the distribution of civilization, it determines the food supply, it determines the state of health and degree of human expenditure of mental and physical energy, and, indirectly, it determines the nature of our work and the character of the games and pastimes of our leisure hours.

Projects

1. To demonstrate by means of wall charts the likenesses and differences of cyclones and tornadoes.

2. To investigate the relationship of forest regions to areas of greatest rainfall.

Suggestion.—Report your investigation in the form of a theme illustrated with maps.

3. To make a study of the theories relative to hail storms and the formation of hail.

Suggestion.—Report the results of your study in the form of a paper illustrated with appropriate drawings.

4. To work with a prism and spray of water from a garden hose in order to discover the conditions that determine the location, formation, and appearance of the rainbow.

5. To learn how to use an aneroid barometer as an instrument for forecasting the weather.

6. To know the history of one or more of the great tornadoes or hurricanes that have occurred in the United States.

Suggestion.—By means of wall chart or blackboard drawings give origin, development, path, etc.

7. To investigate the climatic conditions that exist during the summer and winter seasons in Portland, Maine, and Portland, Oregon, in order to determine which of the two regions has the better climatic conditions.

Suggestion.—Compare their latitudes and each element of the climate. Obtain, if possible, first hand information from the Weather Bureau. Write the chamber of commerce in each city regarding its climatic advantages and disadvantages.

8. To make a visit to the Weather Bureau Station in order to interview the director of the station regarding weather instruments, the making, sending, and receiving of reports, and the charting of a weather map.

Suggestion.—Report the trip in the form of a theme.

9. To investigate:

(*a*) the theories regarding the cause of lightning,

(*b*) the use of lightning rods,

(*c*) safety-first rules for the avoidance of danger from lightning, and

(*d*) first-aid methods to one suffering from lightning shock.

10. To make a collection of weather proverbs and sayings and to account for the origin of each particular proverb and saying.

11. To write a paper setting forth the importance of the Weather Bureau Service and if possible to enumerate instances wherein the Weather Bureau has rendered special service, and to show the value of such service.

12. To make a study of the theories regarding the causes and conditions that bring about snowfalls, and regarding the formation of the perfect snow crystals.

Suggestion.—If possible exhibit pictures or lantern slides of various patterns of snow crystals. Look for articles and pictures of snow crystals by Wilson A. Bentley.

13. To make collections of pictures, poems, and descriptive articles pertaining to weather, climate, winds, rains, seasons, storms, sun, heat, cold, etc., in order to gain a knowledge of these forces of nature from the standpoint of literature and art.

Suggestion.—In your report display for class purposes your best pictures, and read the poem or article that you think is of the greatest merit.

14. To make a study of the climatic conditions that exist in the region of the home in order to make adjustments in food, clothing, and general home conditions.

CHAPTER XI

GOOD AIR AND HEALTH

Object.—To make a study of the causes and conditions that contaminate the air of our homes and cities and to find means for correcting whatever unfavorable conditions are found to exist.

Air and Life.—When we build a fire in a stove, we are well aware that in order to have a continuous supply of heat two materials, oxygen and a fuel, must be constantly present. Likewise, all animal life requires a constant supply of oxygen and foods. The foods find their way into the body by the various processes of digestion and absorption that take place while passing through the stomach and the intestines. The absorbed foods which are distributed by the blood are the fuels of the body. However, the absorbed foods are valueless unless accompanied by a supply of oxygen. In order that oxygen may be available nature has provided our bodies with a set of organs, the lungs, whose special duty is to provide the blood with ample supplies of pure oxygen and to collect waste materials from the blood. And so, on the average of eighteen times per minute, we inhale a quantity of air and rob it of a portion of its oxygen and then exhale it back into the air charged with the waste poison gathered from the lungs. This means of supplying the blood with oxygen and carrying away waste materials is known as the process of *respiration*.

The process of respiration in all animals is quite similar, but man has housed himself in well-made buildings in which supplies of fresh air are more or less shut out and poisoned air is shut in. Again, man has built great cities in which every form of business and industry is carried on; and when so many great activities are brought together in a limited space, the atmosphere soon becomes clouded with smoke and dust and filled with foul odors of every sort. Every morning and every evening in every city through the United States great masses of humanity

travel in street cars filled with crowding, breathing, steaming, sneezing, and coughing individuals that inhale each other's foul and germ-laden exhalations. Since the process of respiration is carried on in one of the most delicately organized systems of the body, polluted air gives rise to conditions that are especially unfavorable to good health and high efficiency. Hence the purpose of the theme of this chapter is to direct attention to those conditions that give rise to unfavorable air conditions within our homes and community and to bring about preventive means wherever such conditions are found to exist.

CARBON DIOXIDE IN THE AIR

Object.—To examine the air in the school and the home for the presence of carbon dioxide.

MATERIALS.—Bottles of lime water. Glass dishes or watch glasses. Six to eight inches of glass tubing.

PROCEDURE AND OBSERVATIONS.—1. Recall the preparation, properties, and tests given for carbon dioxide in Chapter II.

2. By means of a piece of glass tubing pass the breath from the lungs through lime water. Record your observations and conclusions.

3. Place a few drops of lime water in a watch glass. Breath gently on the surface of the lime water. What takes place on the surface of the lime water? Is this a good test for the presence of carbon dioxide gas?

4. Place a layer of lime water in two more watch glasses or glass bowls and allow them to stand in different places exposed to the air. At intervals of ten minutes examine the surface of the lime water in each vessel. What do you observe? What is your conclusion regarding the presence of carbon dioxide gas in the air? Name two sources that give carbon dioxide to the air.

5. Repeat (4) out of doors. In which case does the air contain the more carbon dioxide? Account for this difference.

6. What is your conclusion regarding the amount of carbon dioxide in the air of crowded street cars, theaters, and other public places in which dense crowds are in the habit of gathering?

7. Is carbon dioxide gas beneficial or harmful? Since crowded cars and large gatherings in public places will continually occur, how is air laden with carbon dioxide to be removed or avoided?

CULTURE MEDIA FOR MICRO-ORGANISMS

(Prepared by Teacher and One or More Pupil Assistants)

Object.—To prepare a culture media favorable to the growth of micro-organisms.

APPARATUS.—Steam sterilizer, or double cooker. Dry sterilizer or sheet iron box that will stand heating. Four dozen Petri dishes. Three or four beakers, 1000 cc. and 500 cc. Measuring glass, 500 cc. Filtering funnel. Two Erlenmeyer flasks, 500 cc. Four dozen test tubes.

MATERIALS.—1 gallon distilled water. 10 grams of each of the following materials: agar-agar, salt, peptone, Liebig's beef extract. Some cooking soda. Dilute hydrochloric acid.

PROCEDURE.—1. Dissolve 10 grams of beef extract in 1 liter of water.

2. Then add 10 grams of well broken agar-agar.

3. Add 10 grams of salt.

4. Add 10 grams of peptone.

5. In order to dissolve the agar-agar, heat the mixture, taking constant care not to burn the contents. If convenient place the flask in a double cooker.

6. Divide the solution into two parts, marking one *A*, and the other *B*.

7. Add just enough cooking soda to *A* to make it faintly alkaline—just enough to turn red litmus blue. Add two or three drops of dilute hydrochloric acid to *B* or enough to make it slightly acid. Bacteria grow best in *A*, while molds grow best in *B*.

8. Filter solution *A* into Erlenmeyer Flask marked *A*; and *B* solution, into flask marked *B*. In order to filter, place a layer of absorbent cotton within the funnel which rests in the Erlenmeyer flask. The funnel and the Erlenmeyer flask are placed in the inside vessel of a double cooker in order to keep them hot while filtering. The filtering may be done within the steam sterilizer, in which case the liquid readily filters. If the solution is not clear it must be filtered a second time.

9. Plug the mouths of flasks *A* and *B* and boil the flasks in the cooker for half an hour.

10. The solution is called *nutrient* agar-agar and may be stored away as a stock solution, or it may be poured while hot into Petri dishes which have been sterilized in the dry sterilizer and then kept free from dust. Some sterilized test tubes should be one-fourth or one-fifth filled and immediately plugged with absorbent cotton. The coated Petri plates and partially filled test tubes should all be placed in the steam sterilizer and sterilized once or twice before using. The covers of the Petri dishes should be sealed on removal from the sterilizer and stored in a clean case until wanted. All Petri dishes containing solution *A* should be so labeled for bacteria; solution *B*, for molds.

DUST AND MICRO-ORGANISMS OF THE AIR

Object.—To make a study of dust for the purpose of determining the presence of micro-organisms.

MATERIALS.—Coated and sealed Petri dishes.

PROCEDURE.—Pupils are to expose coated Petri dishes. Make assignments for as many varying conditions as are conveniently possible. In each

case expose two dishes, one marked for bacteria and the other for molds. Do not break the seals until ready to make the exposure. Make the exposure for exactly one minute unless otherwise directed. Reseal and write date, time, and place on label.

Suggested exposures:

1. To air in recitation rooms.
2. To air in halls in which pupils are passing.
3. To air in halls in which pupils have not passed for half an hour.
4. To air in a street in which much traffic is passing.
5. To air in a room which is being cleaned with a broom and dry dust rag.
6. To air in a room which is being cleaned with a vacuum sweeper and oil mop.
7. To air in which some one is brushing clothes.
8. To air in large open spaces or parks.
9. Above the coating of a Petri dish open your mouth and exhale the air of your lungs as completely as possible.

Set the Petri dishes aside and after 4 or 5 days observe daily the development of colonies (spots) of bacteria and molds.

Observations.—Which plates show the greatest number of colonies? What is your conclusion?

Which is the more effective dust remover, the broom or the vacuum sweeper? Even if there were no bacteria or molds would you consider the vacuum sweeper the more efficient?

Should one brush one's clothes in the living rooms of the home? Give your reasons.

Draw other conclusions from the results observed in the Petri dishes. Make as many comparisons and contrasts of the various results as you are able.

Should foods for sale be exposed to the air of the street or enclosed in sanitary cases? Reasons.

SUNLIGHT. BACTERIA AND MOLDS

Object.—To study the effects of sunlight on the growth and development of bacteria and molds.

Materials.—Six coated Petri dishes.

Procedure.—Expose the coatings of the six Petri dishes to the air of the school for a period of 2 minutes. Place three of the dishes in a warm dark place and the remaining three in a warm place exposed to direct rays of the sun.

Observations.—After 4 or 5 days observe daily. Is sunlight favorable or unfavorable to the growth of bacteria? Is sunlight in any way related to good air in our homes? How is sunlight admitted to our homes? What is meant by "airing and sunning our rooms and clothing?"

AIR POLLUTION. HOME WORK

Object.—To make a survey of the community about the home in order to discover causes of air pollution and to seek preventive means for each discovered cause.

PROCEDURE.—Each pupil makes a survey of the district of the city in which he lives. In making the survey consider the following factors and suggestions:

OBSERVATIONS.—1. Odors. Are there any objectionable odors in the air about the home? If there are odors determine their causes as follows: (*a*) uncovered garbage cans; (*b*) decaying rubbish heaps; (*c*) poorly kept chicken yards; (*d*) open sewers; (*e*) garbage dumps; (*f*) layers of filth in uncleaned streets and alleys; (*g*) manufacturing plants. Is there a board of health in your city? Has it the authority to enforce the removal of conditions that give rise to objectionable odors?

2. Smoke. Large areas of the United States use bituminous coal as a fuel for heating the homes. The chimneys of homes using bituminous coal usually pour forth dense volumes of black smoke every time fresh coal is added to the fire. So long as the gases and oils are distilling out of the coal, a black cloud of soot issues from the chimney.

How many residences and other buildings have chimneys from which pour forth soot clouds three or four times per day for 20 or 30 minute periods?

What is the effect of these volumes of soot and dirt upon the air in the community?

In what way is smoke and soot a nuisance to the housewife? To the goods on a dealer's shelves? To appearances of dwellings and buildings? To clothing? To health? To the happiness of a people?

Is there a smoke inspector in your city? What are his duties? Are there any anti-smoke laws for him to enforce? Do the people think it worth while to have anti-smoke laws and to have them enforced?

Coke, anthracite, anthracite briquettes, and semi-hard coals are smokeless fuels. Are they available in your city? How does the cost of each grade compare to that of bituminous coal? Do you consider it possible to make your city smokeless? Give your reasons. Do you think it worth while to have a smokeless city? Reasons.

3. Street cleaning. Is there a street cleaning department in your city? What methods do they use for cleaning the streets—sweepers, flushers, or street vacuum sweepers? What methods do you favor? Are all methods applicable to all streets? Are all the streets in all sections of the city kept clean? If not, why not?

Is the department able to keep the dust down, or do large amounts constantly blow up with each and every light wind that blows? If your city does not keep the streets free from dirt and dust, it is the duty of the health department, health leagues, civic societies, etc., to look into the matter and to make provision for whatever assistance may be required.

4. Hauling and draying. How are sand, ashes, dirt, cleanings, sweepings, coal, lime, cement, etc., hauled through the streets of the city? Do the city ordinances require that such materials shall be covered when hauled through the streets? If not, why not? If there are such ordinances, are they enforced?

5. Other factors. What other factors of pollution are you able to discover? Are they preventable?

VENTILATION. HOME WORK

Object.—To examine the methods employed to supply fresh air to the rooms in which we live and work in order to know whether the conditions are favorable or unfavorable and to suggest improvements when conditions are found to be inadequate or poor.

Procedure and Observations.—How is fresh air admitted to the various rooms in your home? What provision is made for warming the fresh air in cold weather? Is there any provision made for the addition of moisture to the heated air before it enters the living rooms? Which has the greater capacity for moisture, cold air or warm air? When we breathe warm dry air, what is the effect upon the linings of the nose and throat? Is it essential when heating cold air to add the proper amount of moisture before admitting the heated air to the living rooms? How will you determine the relative humidity of the air in your home? At what season of the year is the relative humidity of the air in the living rooms found to be low? Why?

If your home is heated with stoves, how will you admit fresh air and allow the vitiated air to escape? How will you add the required amount of moisture to the air in the room?

If your home is heated with a hot air furnace, how is the fresh air admitted, and the vitiated air allowed to escape? How is moisture added? Is the amount added sufficient? How do you know? If the amount is inadequate, how can you bring about improvement?

If your home is heated by hot water or steam radiators, how is fresh air admitted? How is moisture added? Is the amount of moisture adequate to give a relative humidity of 55%? If the humidity is found to be low, is it possible to make simple provision for the addition of sufficient moisture to the heated air? How?

(Work to do at school) How is fresh air admitted to rooms of the school that you attend? How does the vitiated air escape? Is the air in motion in all parts of the room, or are there corners in which the air is dead—no movement? Make a test with a candle flame for sections of dead air, or, better, hold the mouth of a hydrochloric acid bottle near to the mouth of an ammonia bottle and watch the directions taken by the white clouds in the various parts of the room. Is it possible to trace the air currents of fresh air as they enter, and the exit of the currents of vitiated air? Is

the room well ventilated? Has the air of the school room the proper humidity?

Has the air of the school room the proper temperature? How is the temperature controlled?

Request permission for the teacher and engineer to conduct small groups of pupils on a tour of inspection of the heating and ventilating systems of the school, remembering at all times that such tours are for the purpose of instruction and not for amusement. Consult Fig. 100 and compare it with the system used to heat the school building.

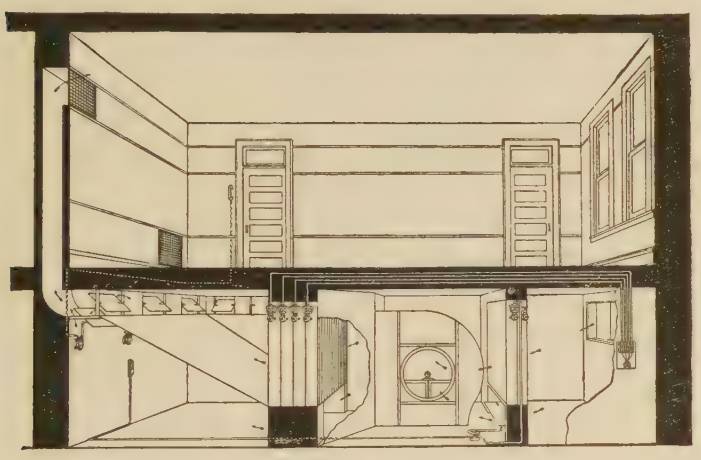


FIG. 100.—Plenum hot-blast system with thermostat control. (*From Tower, Smith, Turton, and Cope's Physics.*)

The Composition of the Air and the Effects of Respiration.—Thus far experiments and experience have taught us that the air is made up of gases, the chief of which are oxygen and nitrogen, with varying amounts of water vapor and carbon dioxide. In pure country air and even in and about cities the amounts of carbon dioxide gas present in the air are exceedingly small. Indeed, so small are the quantities of carbon dioxide that it requires fairly accurate work on the part of a chemist to measure the minute traces that are present. However, the air in doors is very much different. When people sit or work in closed rooms that have no provision made for the circulation and renewal of the air, the air becomes stale and foul. This is due to the fact that every person in the room is taking air into his lungs and, after removing a portion of the oxygen, exhaling

air burdened with carbon dioxide, water vapor, and traces of organic waste. In order to know exactly what changes take place during the process of respiration, chemical analyses have been made of both the inspired and the expired air. The results which have been obtained are given in the following table:

	100 volumes of inspired air	100 volumes of expired air
Oxygen	20.80	16.02
Carbon dioxide	trace	4.38
Nitrogen	79.20	79.60
Water vapor	variable	saturated
Organic matter	....	trace

The above analyses indicate that under ordinary conditions the air loses oxygen to the extent of 4.78% and gains carbon dioxide to the extent of 4.38%, traces of organic matter, and water vapor to the point of saturation. It is these changes that disturb our health when expired air is rebreathed for any length of time.

Respiration and Habits of Exercise.—The body cavity is divided by a muscular membrane, the diaphragm, into the upper and lower cavities, as shown in Fig. 103. The upper or chest cavity is known as the *thorax*, while the lower cavity is known as the *abdomen*. The lungs occupy the greater part of the thorax and are separated from each other by a space occupied by the heart, many large blood vessels, and the esophagus or the food gullet.

On its way to the lungs the air has to flow through a number of passages. First the air is taken into the nasal cavity, where it is exposed to a wide surface of moist mucous membrane. Here the air is warmed, moistened, and cleaned—freed of dust and bacteria. The nasal cavity conducts the air to a space called the *pharynx*, which in turn passes the air to the *larynx* (Adam's Apple). Fixed to the top of the larynx is a wonderful little device resembling a trap door, glottis and epiglottis, which permits only the inspired air to enter the larynx. On entering

the larynx the air passes between the vocal cords to the *wind pipe* or *trachea*, which conducts the air to the lungs.

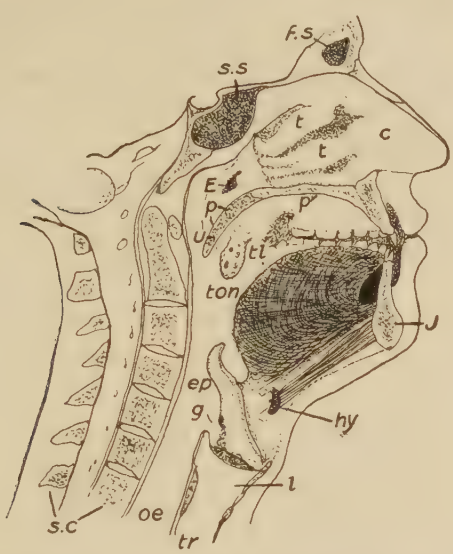


FIG. 101.—Diagram showing nasal cavity, *ctl*; mouth and throat; epiglottis, *ep*, and glottis, *g*, are shown raised and extending into the lower portion of the pharynx; *l*, larynx; *tr*, trachea; *oe*, eosphagus; *tl*, tonsil; *p'* and *p*, hard and soft palate; *u*, uvula. (*From Holmes' Animal Biology.*)

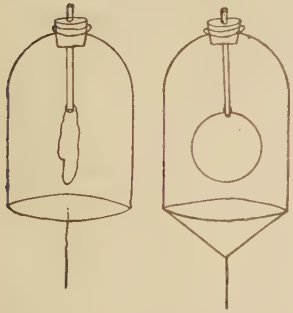


FIG. 102.—Diagram to illustrate the effect on the air content of the lungs of depressing the diaphragm. (*From Holmes' Animal Biology.*)

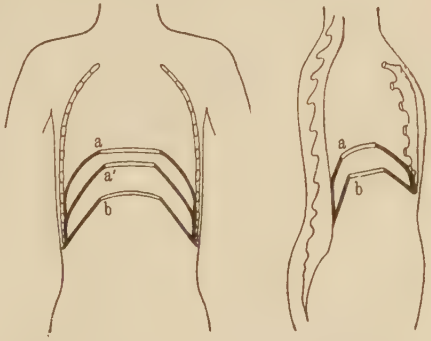


FIG. 103.—Diagram showing the position and shape of the diaphragm at rest *a* and during inspiration *a'* and *b*. (*Boruttau*). (*From Brubaker's Textbook of Physiology.*)

In order to understand better the conditions that control the flow of air to and from the lungs it is desirable that we construct

a piece of apparatus like that shown in Fig. 102. On drawing down the rubber diaphragm there is a tendency to produce a vacuum within the bell jar. This condition of affairs is prevented by the flowing of air through the glass tube and into the bladder or balloon attached to the lower end. When the diaphragm is released the air in the balloon is driven out. While doing this experiment we should observe that the filling and the emptying of the balloon depends entirely upon a difference of air pressure caused by the action of the diaphragm. The more deeply the rubber diaphragm is pulled down, the more distended becomes the balloon. If we force the diaphragm upward into the bell jar, the balloon becomes completely collapsed.

In our bodies the chest cavity is enclosed by an arrangement of ribs and muscles. The upper ribs are more or less rigidly attached to the spine and to the *sternum* or breastbone, but the lower ribs and their attached muscles are capable of considerable motion. When the muscles attached to lower ribs produce an enlargement of the chest cavity, the diaphragm descends. When the muscles produce a contraction, the chest cavity is decreased, and the diaphragm ascends. The various positions of the diaphragm are shown in Fig. 103. In both movements the lungs play an entirely passive part, their movements being entirely determined by the pressure of the air within them and by the movements of the walls of the chest and the diaphragm.

Respiration and the Need of Exercise.—Since the chest cavity cannot be greatly contracted, it is quite evident that the lungs cannot be entirely emptied of their air content. When the lungs are fully extended, their capacity for the average person is about 330 cubic inches. During ordinary respiration the lungs seldom contain more than 230 cubic inches or less than 200 cubic inches of air. However, during ordinary breathing we inhale or exhale no more than 20 cubic inches of air. This is a small amount when compared to the total capacity of the lungs. The air remaining in the lungs is lodged in the small air sacs at the end of the many fine bronchial tubes that branch from the bronchi as shown in Fig. 104. The air in the air sacs is never completely changed or replaced by the incoming fresh

air. Indeed, in some of the air sacs the air may not be renewed for hours. This is especially true of the air in the lungs of people who work at desks and do similar light work in which there is little or no muscular action. Hence, persons who are engaged in any kind of indoor work are in need of outdoor exercise of a kind that will induce deep breathing and thus the renewal of air in every air sac in the lungs. For young people the following games, sports, and pastimes are beneficial for their wholesome effects on the respiratory systems—swimming,

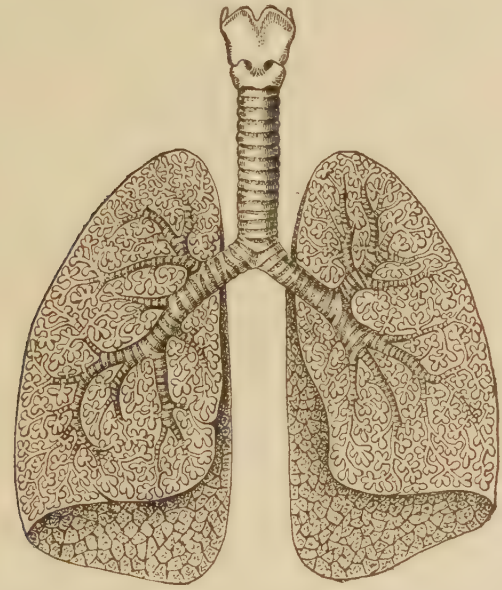


FIG. 104.—Diagram showing the larynx, trachea, bronchi, and lungs; the ramification of the bronchi, and their division into lobules. (*From Brubaker's Textbook of Physiology.*)

rowing, skating, tennis, games of ball, climbing, and similar activities. For the older class golf, riding, rowing, casting, and, similar moderate activities are beneficial for the maintenance of right habits of respiration.

Humidity and Its Relation to Health.—On summer evenings when the temperature ranges from 60°F. to 65°F. we sit clothed in light summer garments in the open air of porches and pavilions. At such times we are usually quite comfortable and have little complaint to make concerning the existing conditions.

However, the degree of comfort is entirely dependent upon the amount of moisture that is present in the air. If the amount of moisture is too abundant, we complain that the air is oppressive or "muggy and sticky;" but when the air is too dry, the delicate mucous membranes of the nose and throat begin to suffer. On the whole the average climate of late summer evenings is delightful and invigorating on account of a proper balance of humidity and temperature.

In winter when low temperature exists out of doors we endeavor to create by means of various heating and ventilating

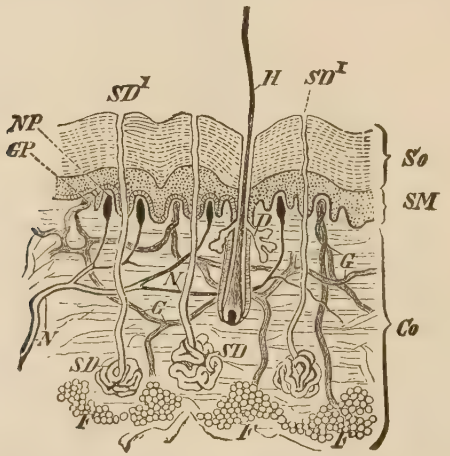


FIG. 105.—Section of the skin of man. *Se*, Epidermis; *Co*, dermis and subcutaneous layer of connective tissue; *F*, fat, *SD*, sweat gland; *SD'*, sweat duct; *G*, blood vessels; *N*, nerve; *NP*, nerve papilla; *H*, hair; *D*, sebaceous gland *GP*, pigment layer. (*Highly magnified from Weidersheim.*)

devices a suitable indoor climate. However, this artificially created indoor climate falls far short of producing conditions as favorable as the average climate of summer evenings. The reason the householder fails to obtain better indoor climatic conditions is that he fails to keep the proper balance between temperature and humidity. He forgets that cold air has little capacity for water vapor; and thus, when he heats it up to room temperature, he has hot dry air entering the living rooms of his home. That is, the relative humidity of the hot air is too low, and when the humidity falls much below 50%, the delicate

mucous membranes of the nose and throat begin to suffer, the lips become parched, and the skin is likely to be too dry. The results of such effects cause people to become irritable and nervous and the general conditions of their health to decline.

Again, continued living in excessively dry air causes the delicate linings of the nasal passages to become swollen and spongy. This condition of affairs lays the foundation for catarrh, much headache, and general ill health. Furthermore, our bodily resistance becomes so lowered that we fall prey to bacteria that develop frequent colds, bronchitis, tuberculosis, pneumonia, and kindred ills.

Again, nature has effected a means of regulating the temperature of our bodies. When our bodies become heated by excessive exercise or labor, perspiration is poured forth from every pore in the skin. The evaporation of the perspiration is a cooling process; and since this process takes place on the surface of the body, great amounts of heat are carried away. On a summer day when the temperature reaches 90°F., or more, perspiration is secreted abundantly, and the vessels of the skin are opened wide and large amounts of blood are circulating in the skin and tissues near the surface. However, as the temperature diminishes, the flow of perspiration grows less, and the amount of blood circulating in the skin and upper tissues grows less. At 60°F. the vessels of the skin are so contracted that but very little blood circulates in the skin, and at the same time greater quantities flow through the internal organs. By this means the internal temperature of the body remains constantly at 98.6°F. When one who is thinly clad enters a room of hot dry air, he experiences chilling effects on account of the rapid evaporation of the moisture on the surface of the body. This chilling effect results in the closing of the pores and the driving of the blood to the central organs. Such a concentration of blood about the central organs gives rise to congestion and symptoms of ill health. When the air is properly warmed and humidified, these effects are less frequent, and the health is conserved.

The Necessity of Air Movement and Supplies of Fresh Air.— While much has been said about the temperature and the humid-

ity of the air within our living rooms, they are not the only factors governing good air conditions. When there is no movement in the air of the room in which we sit or work, the layers of air immediately surrounding our bodies become saturated with vapors, odors, and carbon dioxide given off by the lungs and skin. Such a condition of affairs causes us to become very uncomfortable and much distressed. When the air is set in motion, the vapors and carbon dioxide are dispersed, and we suffer no ill effects from these sources. However, if we go no farther than merely to circulate the air from one place to another within a room in which people are congregated, we shall soon find the whole mass of air heavily laden with moisture and carbon dioxide. To relieve this condition we must replace the stale air with supplies of fresh air. Good air conditions are possible only when the following four factors are in existence and properly regulated: (1) temperature; (2) humidity; (3) air movement; and (4) a supply of fresh air.

Window Ventilation.—The means employed to ventilate any particular dwelling, school, or other institution in which we live and work depend greatly upon the method of heating that is employed. When we are heating with stoves, ventilation is brought about by the proper adjustment of the windows. Window ventilation, while simple in itself, is difficult to adjust to the satisfaction of all when there are many gathered in the same room. Usually those sitting near windows complain of drafts, while those at greater distances receive no appreciable benefits at all. Many simple devices known as window ventilators may be employed in rooms in which few people are present. When we are ventilating by means of windows, it is well to open wide the doors and windows at various intervals and thus allow a complete change of air to take place. The complete renewal of air by window flushing is an excellent means of freshening a room no matter what method of ventilation may be employed. The fresh outside air blowing through a room carries away accumulations of odors, pockets of vitiated air, and varies the air conditions within a room, and thus reduces the deadening effects that arise from the constant monotony of an indoor climate.

Hot Air Furnaces and Ventilation.—When a building is heated by means of a hot air furnace, we find an excellent method for heating constant supplies of fresh air. (Review hot air furnace, Chapter VII.) Moreover, this method of heating affords an easy means of supplying moisture to the air. However, the humidifying of the hot air by hot air furnaces is seldom, if ever, adequately done. The water pans are usually placed too low in the air chamber and opposite the ash box, where only a small amount of cold air passes. Furthermore, the cold air is more or less saturated and can pick up more moisture only after it is heated. Consequently, homes heated by means of hot air furnaces have an indoor climate of a desert dryness that is alarming. A wise householder takes pains to see that the water pans are properly placed and fitted with asbestos wicks or other devices that provide large surfaces for evaporation. By this means the relative humidity of the dry air, which is usually less than 30%, can be raised to 50% and often to a more preferable one of 60% to 65%.

Indirect System of Heating and Ventilation.—When we are using hot water or steam heating systems, two or more methods of ventilation may be employed. When the steam or hot water radiators are placed in the room to be heated, we employ the same methods of humidifying and ventilating as when we are using stoves. That is, the escape of vitiated air and the entrance of fresh air are regulated entirely by adjustment of windows and doors. The humidifying of the air is accomplished by means of radiator pans that hold the evaporating water. While this method of direct heating with steam and hot water radiators is very common, it is the most unsatisfactory arrangement from the standpoint of ventilation.

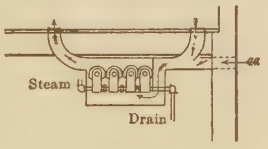


FIG. 106.—Indirect system of heating.

Sometimes the hot water or steam radiator is placed in a box immediately under the floor as shown in Fig. 106. The cold fresh air is admitted through a cold air duct in the wall and is heated while passing the several coils of the radiator. This manner of receiving fresh supplies of warm air is known as

indirect heating. While it is a good method for warming and supplying fresh air, the indirect heating system usually has no means of supplying the necessary humidity to the heated air.

Another way of heating and ventilating when we are using steam and hot water is to set the radiator over a cold air duct as shown in Fig 107. The hot radiator radiates heat into the room and at the same time warms the incoming cold air, which circulates through the radiator coils before passing into the room. This method of heating the room and the incoming supplies of fresh air is known as the *direct-indirect system*, and like the indirect system it has no definite means of supplying the required amounts of water vapor to the heated air. Since it is necessary to set the coils against the outside walls of a room, the direct-indirect system of heating and ventilating is uncertain in its action. For in winter the outside walls are cold, and therefore, near their surface there is a downward current of cold air. This downward current of cold air is often heavy enough to reverse the direction of the air through the coils of the direct-indirect system. Since the coils are against the outside walls they are at the greatest possible distance from the boiler. Long steam or water pipes mean a loss of heat and unnecessary fuel bills.

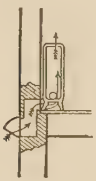


FIG 107.—Direct-indirect system of heating.

Air, Dust, and Bacteria.—While the atmosphere is not the normal habitat of bacteria, molds, and yeast, these micro-organisms are all found in the air. In a given quantity of air the molds and bacteria are usually abundant, while yeast spores are less common. These micro-organisms may be found free in the air, attached to particles of dust, or enclosed in minute droplets of water. Bacteria and yeast are usually associated with dust particles that have been pulverized from the materials in which they have been growing. It must not be thought, however, that all dust particles have micro-organisms attached. Sweeping a floor or rug, dusting with dry cloths and dry mops, brushing clothes, etc., increases many times the dust and bacteria content of the air. Also tiny germ-holding droplets may be

scattered by the splashing of sewage or putrefying liquids, and in speaking, sneezing, or coughing.

The nature and kind of bacteria found in the air depends entirely upon the nature of the surface with which the air currents come into contact. Streets in which dirt and organic filth are allowed to accumulate and become pulverized and disturbed by vehicles and pedestrians contribute a large number and variety of kind. On windy days bacteria are more numerous than on quiet days, more abundant in city than in country air, and fewer at levels high above the surface of the street. Bacteria and dust are washed from the air during rains, and bright sunlight destroys many varieties. Bacteria and yeast are not given off from moist surfaces; indeed, moist surfaces collect and retain whatever bacteria and particles of dust come into contact with them. Nature makes use of moist surfaces for freeing the air of dust and bacteria, and for this reason the air while passing through the nasal cavities is brought into contact with a many-folded mucous membrane that gathers the dust and bacteria from the inspired air.

Methods of Cleaning; Brooms and Vacuum Sweepers.— Dust is everywhere, but the worst kind of dust is that which is confined within the four walls of a room. This kind of dust is always germ-laden, because it is infested with organic matter thrown off by human bodies. In city hospitals, where the most rigid possible sanitary conditions prevail, bacteria are found to be 100 to 200 to the cubic yard of air. In open air under normal conditions bacteria are found to the extent of 100 to 150 per cubic yard. These conditions are not especially unfavorable to life. In city streets bacteria exist anywhere from 3000 to 5000 per cubic yard, and in some work shops several times this number may be present. In the average home where the rooms are only fairly well ventilated, and house cleaning is done by the ancient method of the broom and the dust cloth, the number of bacteria may be anywhere from 500 to many thousands per cubic yard. Happily, there are millions of germs in every human body that are fighting for health, and so long as these health-germs are in the majority we are well. But whenever the germs of disease outnumber

the germs of health, we decline, grow weary, tire, become exhausted and sick with lung diseases, especially pneumonia and tuberculosis.

However, if we would be well, we must devise, not a plan by which the dust and bacteria are simply scattered through the room by sweeping and dusting, but a plan by which they are picked up effectively and destroyed. Cleaning with a broom or brush removes the large pieces of debris that litter the floor, but raises and distributes the fine dust and bacteria throughout the confined air of the room. The dust floating in the air not only settles on the furniture, but falls on the carpet and hangings, into crevices and corners; indeed, the fine dust is never removed from rooms in which brooms, whisk brooms, dust cloths and feathers are the main means of removing dirt. Furthermore, sweeping with a broom and then dusting off the dust-laden articles are crude, laborious, and primitive cleaning operations which were all right when people lived mostly out of doors, but for the modern home they are unsuitable and unsatisfactory.

If in our homes the floors were made of polished maple without crack or crevice and with corners rounded to prevent dust deposits, we could do an effective job of cleaning with an oil mop. But our homes are not so simply provided. The floors are more or less inferior, and besides they are fairly covered with rugs and carpets which, at all times, are well laden with the most minute sort of dust. There is only one way to keep any kind of home sweet and wholesome, and that is to pick up the dirt, dust, and disease-germs by the suction process. By this means the air, dust, and bacteria are drawn out of the room, leaving it free from destroying and death-dealing agencies that are always present in broom-swept homes.

Vacuum cleaning machines are of two types, portable and fixed. There are many designs of each type on the market. The portable type is usually known as a *vacuum sweeper*, Fig. 78, which usually consists of a revolving brush, an exhaust fan, and a dust-receiving bag. The fixed type is installed in the basement and is connected with a central suction pipe running through the partitions of the house. Base board inlets in the various rooms connect with the central suction pipe. The

housekeeper inserts the end of a hose into a baseboard inlet, and turns an electric button which starts the machine running in the basement. The suction draws the dirt and dust down through the central suction pipe into the dust bucket of the machine, Fig. 108.

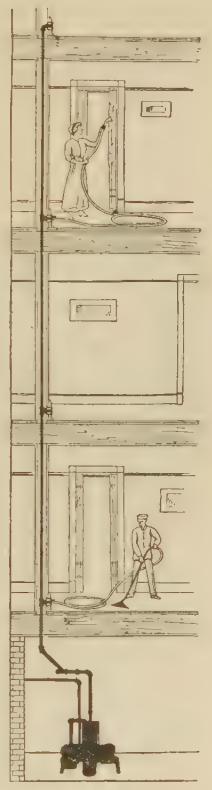


FIG. 108.—The simple, sanitary way of cleaning, fixed type.

Keeping the Air in Cities Clean.—Every activity of city life gives rise to dirt and dust, which are always accompanied with greater or smaller numbers of bacterial forms. Dust and dirt are continually being raised from unpaved streets and alleys, unoiled macadam roadways, unswept pavements, street sweepings, uncovered loads of sand, cement, coal, stone, and various other materials that are being hauled through the streets of the city. Street cars, trucks, automobiles, wagons, carriages, and the feet of many thousands of pedestrians are continually pulverizing all forms of dirt and filth masses and thus giving rise to a dust so fine that it rises and floats with every breeze that blows. The alarming fact is not that dirt and dust are daily distributed, but that they are allowed to accumulate so that the cinder which afflicts the eye today may have been deposited in the alley ash heap a month ago. Again, dirt and refuse at the immediate moment of deposit are least dangerous to health and property. But each succeeding day that the refuse reposes on the surface or flies in the air adds to its dangers through decay—the generation and accumulation of bacteria in combination with other wastes with which it comes into contact.

The Smoke and Soot Nuisance.—During the war the Department of the Interior made an investigation of the use of coal in the factories and in the homes. As was expected, much waste of fuels was found on every hand. In some instances it was found that every fifth shovel of coal that the average fireman threw

into his furnace served no more useful purpose than to fill the atmosphere with a long black stream of soot. In many instances the householder allowed the first one-third of the heat energy to escape through the chimney with little or no resulting heating effect. This loss of heat was due to a lack of knowledge concerning the uses of soft coal as a fuel. Feeding or banking hot fires with soft coal is a waste of fuel. The gases and oils are driven out of the lumps of coal and, being only partially burned, escape up the chimney accompanied with a great quantity of

FIG. 109.—A street sweeping machine which is capable of cleaning about fifty miles of a city's streets per day. The debris is conveyed and stored away in a sealed box carried at the front of the machine. When the box is filled its contents are delivered to a service truck. In this manner the streets are effectively cleaned, and the air is unpolluted with dust and disease germs. (*Courtesy of the Street Cleaning Dept., Cincinnati, Ohio.*)

carbon particles—soot. After the gases have distilled off, the coke remains. The coke burns slowly and evenly with good heating effects and no smoke. Had the coal been properly placed on the fire bed, the gases and soot would have been burned with corresponding heating effects. Information regarding the proper firing of soft coal fuels in various kinds of furnaces may

be obtained from the Department of the Interior. People who are thrifty and wish to conserve in the use of fuels and who wish to aid in securing pure air in their city or community will seek this information and put it to practical use.

Street Sweeping Machines an Aid to Clean Air.—Many cities have become interested in the problem of clean air. The people of these cities are beginning to realize the relation of good air to health, the relation of good air to happiness and proper attitude of mind, and the relation of clear air to clean buildings and general appearances. These cities have installed street sweeping machines, Fig. 109, to replace "white wing" sweepers. The superintendent of streets in one of the large cities of the central west reports, "The new street sweeper is driven by one man and it cleans a stretch seven feet wide and six miles long in an hour, or about fifty miles in a day. If the machine is required to pass up and down a street three times to cover its entire breadth, the sweeper cleans seventeen miles of street in a day. The sweeper has a small brush that cleans the gutter, and a seven foot brush that follows and throws the dirt onto a moving belt which conveys the dirt to a sealed box carried at the front of the machine. No particles of dirt or dust are distributed or raised into the air by these sweepers." Clean-up campaigns in cities should be continuous, and not periodic, as is generally the case.

Projects

1. To make a study of the conditions of humidity in the home and to devise means and methods for maintaining the proper humidity.

Make a written report.

2. To make a study of the various window ventilating devices that are placed upon the market, in order to recommend the most suitable for use in the home.

Make a written report accompanied with collected advertising literature.

3. To make a study of window ventilation and to design and construct a simple window ventilator for use in the home.

Make written report illustrated with drawings of the design, and, if possible, display and demonstrate the constructed window ventilator.

4. To conduct an investigation for the purpose of determining the various agencies that are working for clean air in the city and to decide upon a plan of coöperation.

Write letters to the chamber of commerce, city smoke inspector, building association, welfare societies, health department, etc. Report results in writing with quotations from letters received.

5. To learn how to fire the home furnace with the least waste of fuel and smoke production.

Write to the Bureau of Mines at Washington, D. C., for information relative to this point and report the result of your failures and successes in full.

6. To make inquiry regarding smokeless fuels and to learn their proper uses as such in order to recommend their use in the homes.

Write to the Bureau of Mines for literature pertaining to smokeless fuels. Gather samples of each and display with proper labels attached.

7. To make a study of the heating and ventilating system employed in some large public building or office building.

In your report tell how the air is heated, humidified, renewed, and kept in motion. If possible display a wall chart diagram.

8. To make a study of street oiling in order to become acquainted with the purpose and possible results of such a treatment of streets and roads.

Report in the form of a theme.

9. To look up the laws and ordinances concerning the collection, removal, and disposal of ashes, cinders, garbage, and other wastes, in order to be acquainted, with proper observance of such requirements and to learn how to make complaint of non-observance of the law to the proper official.

Report in the form of a theme. Quote the laws or ordinances.

10. To make a study of the causes and conditions that lead to tuberculosis and to learn the remedial steps that are taken for its cure.

Report in the form of a theme.

11. To make a study of "fresh air schools" and to report the purposes and success of these institutions.

Make your report in the form of a theme.

12. To survey the home in order to determine the possibility and advisability of adding a sleeping porch.

Report in writing.

13. To make a report of the various methods employed for the removal of dust from the presence of laborers in factories and mills.

14. To survey the community in order to list all out-of-door pastimes, games, and sports for the various seasons and to recommend those most conducive to habits of good health.

Report in the form of a theme.

15. To make a study of the principles of hygiene that are concerned with the care of the nose and the lungs.

Consult books on physiology.

16. To investigate the rules and regulations regarding the ventilation of street cars, picture theaters, public lunch rooms, etc., and to report the provisions made for the observance of the required regulations.

Report in the form of a theme. Quote the rules and regulations as provided by the city government. Also, make clear the effects of non-observance of the regulations for good ventilation.

17. To learn what is meant by the term "Preventive Medicine."

Interview the family physician regarding the term and have the city librarian look up one or more representative articles on the topic. Do people, in general, keep so well conditioned that they can resist the attacks of disease germs? Report in the form of a theme.

UNIT III

WATER AND ITS SERVICE TO MAN

CHAPTER XII

THE THREE FORMS OF WATER AND THE USES THAT WE MAKE OF THEM

Object.—To make a study of the forms of water in order to observe the change of one form to another and the relation of heat to these changes.

To make a study of some of the uses of the various forms of water in the arts of man.

Man's Constant Need of Pure Water.—Whenever we go camping our first thought is usually concerned with the availability of supplies of good water. No matter how interesting or otherwise important the selected camping site may be, if there is no supply of good drinking water, the location is not desirable. Although we want shelter and other comforts of life, we do not require them as we require water.

The location of the dwelling sites of man has ever been determined by the presence of springs of wholesome water issuing from the side of some hill or mountain. When the Pilgrims landed in Cape Cod Bay, they sent out an exploring party to find a suitable place for a settlement. An old record tells us that after several days' search Captain Miles Standish and his party "marched into ye land and found divers cornfields and little running brooks, a place fit for situation." The majority of cities started as small villages on the banks or shores of some stream or lake whose waters were fresh and pure.

As our cities grow larger, the problem of sufficient water supply becomes more and more pressing. Again, our modern ideas of living have greatly increased the demand for larger

amounts of water. The small springs and streams that supplied water during the early village days are not sufficient for the needs of a great city. Rome in her early days used the waters of the Tiber, but when she became a city the river waters became polluted with waste materials. Knowing no way of purifying the waters of the Tiber river, the Romans found it necessary to bring water from mountain reservoirs by means of great aqueducts that were often many miles in length. Today, the success of every great city is directly concerned with its supply of pure water.

While the first and most important use of water is for drinking purposes, many other needs dependent upon water have arisen. Water is essential for cleanliness and health. It furnishes power at the water fall, and when turned to steam in a boiler it drives our steam engines. Water is used in the production and manufacture of food, and in the form of ice it is used as a cooling and refrigerating agent.

In order that we may better understand some of the great problems that are directly related to the happiness and welfare of vast numbers of people living together in great city communities, the subject matter of the chapters of this unit is concerned with the study of water and its service to man.

COMPOSITION OF WATER

Object.—To make a study of water from the standpoint of its composition.

Review the experiment concerning the preparation and properties of hydrogen in Chapter II.

(*a*) When hydrogen unites with oxygen what substance is formed?

(*b*) Is water a compound? Explain.

(*c*) Is water an oxide? Explain.

(*d*) Are hydrogen and oxygen elements? Explain.

(*e*) In what respect is water different from hydrogen and oxygen?

Recall project 1, Chapter II. During the development of this project the composition of water was demonstrated. When the water was decomposed, how did the volumes of hydrogen and oxygen compare?

COOLING EFFECTS OF ICE

Students in groups of two or more.

Object.—To determine whether a pound of ice at 32°F. or a pound of water at 32°F. produces the greater cooling effect.

Apparatus.—Scales and weights. Two thermometers. Four beakers, 1000 cc. Iron ring stand. Bunsen burner. Watch or clock.

Materials.—Salt. Water. Crushed ice.

Procedure and Observations.—1. Cool exactly one pound of water to 32°F. by surrounding it with ice and salt.

2. In a beaker weigh out exactly one pound of crushed ice.

3. Place the beaker and crushed ice on a wire gauze supported by a ring stand.

4. Adjust the flame of a Bunsen burner to a medium height and do not disturb this adjustment for the remainder of the experiment.

5. Observing the time, place the flame under the ice and heat until the ice is just melted. Observe the time and temperature. The temperature should be at or near to 32°F.

6. Remove the beaker and water from the flame and set on the beaker containing the pound of water at 32°F. and heat for the same length of time that it took to melt the pound of ice.

7. At the end of the time observe the temperature, which should be somewhere near 176°F.

8. Were approximately the same amounts of heat applied to the ice as to the water?

9. In which was there the least change in temperature?

10. Which stored away the heat with little change in temperature?

11. How many degrees of change in temperature were there produced in the water?

12. Which is the better cooling agent—ice at 32°F. or water at 32°F.?

13. How many times better?

14. Accurate experiments show that a pound of ice is about 144 (176–32) times better as a cooling agent than one pound of water at 32°F.

FREEZING BY MEANS OF EVAPORATION

Object.—To observe the freezing of water by the evaporation of another liquid.

Materials.—Watch glass. Cork. Ether. Water. (Caution: No flames in room with ether.)

Procedure.—Place a large-sized drop of water on a cork and set the watch glass in the drop of water. Fill the bowl of the watch glass with ether. When the ether has evaporated, fill the bowl of the glass with ether and allow the ether to evaporate.

Observations.—When the ether has evaporated, the watch glass should be quite firmly frozen to the cork. Explain in full the causes of the observed results.

Do ice machines cause liquids to evaporate or vaporize in coils about cans of fresh water which finally becomes frozen? Is ether used in ice machines, or liquefied ammonia, or liquefied sulphur dioxide gas? Consult the text of this chapter and text books on Physics and Chemistry.

Is the ammonia gas or sulphur dioxide gas allowed to escape, or is it pumped out of the expansion coils and again compressed to be used over and over again?

Review the factors affecting the rate of evaporation, Chapter IX.

HEATING EFFECTS OF STEAM

Object.—To review the processes of evaporation and condensation in order to understand the heating effects produced by steam.

Review the experiment "Steam Heating" in Chapter VII.

(*a*) Is vaporization a heating or a cooling process?

(*b*) Is condensation a heating or a cooling process?

(*c*) What must be added to a liquid to change it to a vapor or a gas?

(*d*) What must be taken away from a gas to change it to liquid?

(*e*) When a vapor or a gas is condensed, does it give back as much heat energy as it received?

DISTILLATION OF WATER

Pupils in groups of two or more

Object.—To learn how to free water from dissolved and suspended substances.

APPARATUS.—Ring stand. Burette clamp. Wire gauze. Glass tubing. Test tube. Wide mouth bottle or glass. Bottle with stopper. Source of heat.

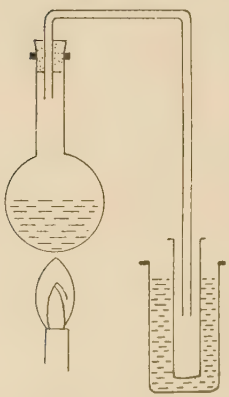


FIG. 110.—Arrangement of apparatus for the distillation of water.

MATERIALS.—Water. Salt. Clay. Sand.

PROCEDURE AND OBSERVATION.—(*a*) Place a small amount of salt in some water in a stoppered bottle and shake. Does the salt disappear—dissolve? Is the solution clear? Is the salt distributed everywhere throughout the liquid? Taste different portions and see if the salt is well distributed.

(*b*) Repeat (*a*) with clay. Does clay go into solution or remain suspended—hanging particles every where throughout the liquid? Does most of the clay settle quickly to the bottom of the bottle? Is the mixture clear? Is clay soluble in water?

(*c*) Repeat (*a*) with sand. Does the sand behave differently from salt? From clay?

(*d*) Define or write a statement concerning solution; suspension.

(*e*) Place salt, clay, sand, and water in the flask and shake vigorously. Which substance went into solution? Which remains suspended? Which settles out rapidly? Distil a few drops of water by arranging apparatus like that shown in Fig. 110.

Does steam pass off from the heated mixture?

Does it condense in the test tube surrounded by cold water? Is the distilled water free from salt, clay, and sand? Taste for the presence of salt. Does the process of distillation free water from dissolved substances?

Do you know other liquids that may be distilled and thus be freed from impurities?

Does the water about the receiving test-tube become heated? Explain.

Does the oil industry depend upon the art of distillation for the winning and refining of the many varieties of oils?

Water, Steam, and Ice.—Water is one of the most abundant and widely distributed substances of the earth. It exists naturally in the states of vapor, liquid, and solid. Since the liquid form is used for drinking purposes and is essential to life, we can safely assume that every inhabitant of the earth is well acquainted with this state of water. The people of the tropical countries are more familiar with water in the liquid state; they see it descend in torrential rains, they fish and bathe in it, and upon it they float their boats and travel from place to place. The Esquimo is well acquainted with all states and forms, but uses and works with the solid forms more than others. Snow and ice surround him for the greater portion of the year, and so he builds his house of the solid forms, builds a sled for transporting foods over trails of snow and ice, and uses snow shoes as a means of travel. The inhabitant of the temperate zone is not only acquainted with all the states and forms of water, but has artificial means of producing steam or ice and adapting them to the necessities and comforts of life. As the degree of civilization advances, more and more uses are being made of each of the states of water—steam for heating, cooking, cleaning, sterilizing, and power; water for drinking, bathing, warming, cooking, and in the producing and manufacturing of foods; and ice for cooling, refrigerating, and controlling hundreds of daily operations of our civilized manner of living.

Composition of Water.—Water is a compound made by the union of two elements, oxygen and hydrogen. One hundred and fifty years ago people believed that water was a simple substance, an element, and that it could not be decomposed or broken down into simpler substances. In 1784 Henry Cavendish, an English scientist, announced that when he burned hydrogen gas in oxygen gas he obtained water as the result.

This discovery was, indeed, quite startling to the people of that time, who found it hard to believe that the very water which they drank was a compound of two gases. Later experimental work showed that two volumes of hydrogen always combined with one volume of oxygen to form water; or when water was decomposed, two volumes of hydrogen and one volume of oxygen were always obtained. Since one volume of oxygen is sixteen times heavier than one volume of hydrogen, the composition of water is made up of two unit weights of hydrogen with sixteen unit weights of oxygen. Every time we look upon a body of water, we can think of every nine pounds of it as being made of one pound of hydrogen and eight pounds of oxygen.

These gases are united so firmly that it requires a somewhat powerful electric current or chemical reaction to separate them. During the process of tearing them apart, great quantities of heat energy are absorbed by the two gases. The absorbed heat energy is all given back again when the two gases unite to form water. The absorption of heat energy or the release of heat energy always takes place during a chemical change. This explains why so much heat is released when hydrogen burns in oxygen to form water.

When Cold Water is Lighter Than Warm Water.—We have learned that solids, liquids, and gases expand or contract for corresponding changes in temperature. When a copper bar is cooled it contracts; the greater the cooling effects, the greater the contraction. Water behaves differently. When a body of water is cooled, it also contracts as the temperature lowers; and this it continues to do until the temperature of 39°F. is reached. If we continue to lower the temperature below 39°F., the water, instead of contracting, is actually expanding. As the temperature descends, the water expands more and more until the temperature reaches 32°F. Hence a cubic foot of water at 39°F. weighs more than a cubic foot of water at 32°F., for the simple reason that there is more water in a cubic foot at 39°F. than there is at 32°F.

Since water at 39°F. is heavier than water at a lower temperature, it remains at the bottom of a lake or pond, while the lighter and colder water is at the top. This condition of affairs

escapes the observation of most people, who are better acquainted with the temperatures of the water of lakes and ponds in summer than they are in late fall and winter. The temperature of water in summer is above 39°F., and under these conditions the cold water is at the bottom and the warm is at the top. But in late fall and winter when the cold winds try to lower the temperature of water below 39°F., we find the cold water of 32°F. at the top and the warm and heavier water of 39°F. at the bottom. The cold water on the surface continues to give up its stores of heat to the passing winds and changes to ice.

From what has been said we can readily understand why the bottom of a deep lake never freezes. On account of its lightness the water whose temperature is below 39°F. is forced to remain at the top. As cold weather continues, the layer of cold water becomes a sheet of ice which protects the warm and heavier waters below. Unless the pond or lake is so shallow as to freeze solid, the water at the bottom will never become colder than 39°F. This irregularity of water that results in expansion during a lowering of temperature prevents the waters of the earth from freezing solid. As it is, fish and other forms of life that pass their lives in water find it possible to live through the winter at the bottom of deep lakes and ponds.

The Work of Freezing Water.—When water changes to ice, we find that the ice occupies a greater space than that occupied by the water; indeed 1 cubic foot of water at 32°F. gives 1.1 cubic feet of ice at 32°F. That is, before water can change to ice, expansion must take place. Hence, when water freezes in water pipes, the pipes are usually split by the expansive forces of the freezing water. The splitting of rocks and the swelling up of moist ground during severe freezing spells of winter are caused by the freezing of the water which has penetrated into the pores and cracks of these substances. The wrecking of mountain tops, stone walls, cement sidewalks, and poorly drained roadways is mostly due to the lifting effects of freezing water that found its way into the cracks and crevices of these materials. This action of frost on the rocks and soils of the earth is very beneficial and results in the breaking apart of solid materials that hold plant foods. These foods are used by

the plants as their building materials in the processes of growth and development. Since all animal life is dependent upon the plant kingdom for food, we are able to appreciate the work

FIG. 111.—Valuable plant foods are locked up in the rocks of the earth. Freezing water and other weathering processes release these foods, which are carried by running waters to the farms in the lowlands. (*From The Rio Grande Southern R. R.*)

accomplished by the expansive forces of freezing water. Throughout the countless ages of the earth these forces have been at work liberating the essentials that serve all life as food.

Freezing Water Gives up Heat While Melting Ice Takes up Heat.—Before water can freeze, it must give up a certain amount of heat energy. Likewise, before ice can melt and form water, an amount of heat equal to that given up during the freezing process must be returned. Whether a substance is a solid or a liquid depends upon the amount of heat that is hidden away by the many particles that compose it. We have already learned that when one pound of water has its temperature lowered 1°F., it gives up exactly 1 Btu. of heat energy; or when its temperature is raised 1°F., it takes up 1 Btu. of heat energy. When we change 1 lb. of water at 32°F. to 1 lb. of ice at 32°F. there is no change in temperature, yet the water has given out 144 Btu. of heat energy. Likewise, during the change of ice to water the temperature remains at 32°F., yet each pound of ice has taken up 144 Btu. during the melting process. In short, then, the vital difference between a pound of water at 32°F. and a pound of ice at 32°F. is that a pound of water possesses 144 Btu. of stored-up heat energy. This stored-up heat energy is called *insensible heat* or *latent heat* and is always 144 Btu. per pound (80 calories per gram) for water.

Water is not the only liquid that possesses *latent heat*. Every liquid—alcohol, melted paraffin, and similar materials—possess a given amount of latent heat energy which they must give up before they can freeze and become solids. But water possesses a greater amount of latent heat per pound than any other substance. Hence when ice melts it requires more heat per pound than any other solid. On account of the large amounts of heat given out by cooling and freezing water, winter seasons are held back in regions of large bodies of water. Also, when large quantities of ice have formed during the winter, the spring and summer seasons are delayed by the melting ice and the warming-up of bodies of cold water.

Ice and Its Uses.—Thirty years ago or so the use of ice was largely confined to northern climates in which ice could be cut and harvested from fresh water lakes and ponds during the winter season. As the uses of ice became more and more extended, large cities located to the south of these regions of cold winters sought their supplies of ice in the northlands.

Consequently great quantities of ice were gathered and stored wherever it was found in available quantities, and shipped southward during the summer. Since the supply was always more or less uncertain, ice famines were frequent, and unreasonable prices denied the use of ice to those people whose needs were the greatest. Ice famines and ice shortages that occur during the hot periods of the summer season give rise to many costly results. Dairy products, which are the essential foods of children, meats, fruits, and other perishable foods can not be kept wholesome and free from decay and putrefaction in homes and shops in which ice is not used. Spoiled summer foods give rise to many summer ills and epidemics that often result in a high rate of death, especially among children, whose foods are largely of a perishable sort.

Ice Machines, a Necessity.—The demands for ice have far outgrown the amounts that can be harvested and stored away during the cold months of winter. In fact, sections having cold winters have found it impossible to gather and store away sufficient quantities for their own use. Again, natural ice is so often contaminated with impurities which cause bacterial diseases that people find it unsuitable for many purposes. Shortage of supplies and dangers from disease led people to manufacture artificial ice.

In one of the preliminary experiments water was frozen by the cooling effects produced by the evaporation of ether. This principle is employed in ice plants in which artificial ice is produced. Instead of ether, liquid ammonia is used as the freezing agent. If a can of ether is left uncorked for a length of time, the ether will quickly evaporate and escape from the can. The moment liquid ammonia is released from its container it changes instantly to a gas. Whenever a liquid changes to a gas, heat is always taken up. When ammonia changes from a liquid to a gas, it instantly robs great quantities of heat from everything with which it comes into contact. This property of taking up heat quickly in order to evaporate makes ammonia one of the best cooling agents that we have.

An ice machine is really a very simple device. (See Fig. 112.) It consists of four essential parts: (1) A condensing coil, *C*,

surrounded by circulating cold water; (2) a regulating valve; (3) an expansion coil, *E*, surrounded by a salt solution; and (4) a compression pump called a compressor. The liquid ammonia is stored in the condensing coil. When the regulating valve is opened slightly, the liquid ammonia sprays into the expansion coils, where it robs heat from the coils while changing to a gas. The compression pump withdraws the ammonia gas from the expansion coils and forces it over into the compression coils. In the compression coils the gas is so compressed that it is forced to give up the heat that it robbed in the expansion coils and become a liquid. This simple process goes on

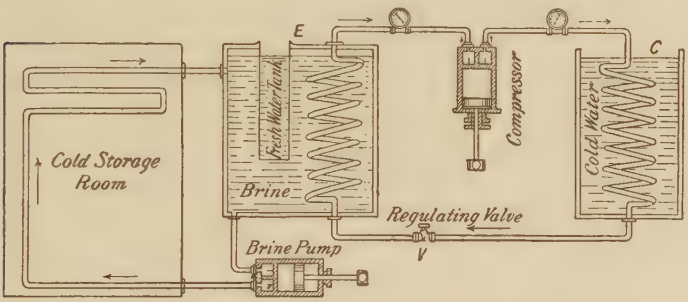


FIG. 112.—Diagram of an ice machine showing how it may be used for making ice and refrigerating cold storage rooms. (*From Tower, Smith, Turton, and Cope's Physics.*)

continually—the gas is compressed and forced to give up its heat and become a liquid, and then the liquid is allowed to change into a gas and take up heat. The expansion coils are continually taking heat away from the salt water and transferring it to vaporizing ammonia. Hence the brine solution is always losing heat and becoming colder. When fresh cans of water are lowered into the cold brine, the fresh water is frozen to ice.

Since artificial ice is made from condensed steam—distilled water, it is quite free from all disease germs and impurities. The cost of artificial ice depends largely upon the price of the coal used to furnish power to the steam engine that drives the compressor, and upon the operating expenses of the plant. Cities located in the southern portion of the United States, as well as

many in the northern portion, find that the cost of artificial ice is less to the consumer than the natural product.

The Importance of Cold Storage.—Ice plants are used not only for the purpose of producing ice, but for producing cooling effects in cold storage plants. Often an ice plant and a cold storage plant are combined. The temperature of the cold storage plant is maintained by pumping the cold brine through a series of pipes that run to all parts of the cold storage room, as shown in Fig. 112.

In the cold storage plants are stored surplus quantities of perishable produce, such as beef, poultry, eggs, butter, fruits, and vegetables. Before cold storages came into use, the markets were flooded with certain foods for a short season. In the spring of the year there is an over supply of eggs. Instead of allowing these eggs to go to waste, they are stored away in cold storage plants and put upon the market in winter months when there is a shortage of egg supply. The result is that cold storage plants keep the price of eggs up in spring and summer and down in winter. Since the cold storage has come into use, many perishable foods are obtainable throughout the year. This distribution of perishable foods throughout the year is exceedingly favorable to our modern way of living.

Refrigeration and Transportation.—Great masses of humanity living in centers like London, New York, Chicago, Philadelphia, and San Francisco require daily huge supplies of wholesome food. The herds of beef cattle feeding on the western plains or the grass lands of Argentina furnish the meat supplies that are so necessary to the welfare of the people who live in the great industrial communities. The cattle are slaughtered at centers not far from their feeding grounds, and the meats thus prepared are packed in cold storage plants. The meats are transferred to refrigerator cars that transport them across the country. Large sea-going vessels are equipped with refrigerating plants which make possible the transportation of the great quantities of fresh meats from New York and Buenos Aires. Hence supplies of wholesome meats in an excellent state of preservation are continually passing to the countless numbers of consumers wherever located.

Not only are meats thus transported, but fruits from Central America and the southern and western United States are shipped in all seasons to all the markets throughout the country. Of all the many and vital factors that contribute to the successes of our present-day manner of living, probably no one of them contributes more to the needs of man than does the art of refrigeration.

The Boiling Point of Water.—Every one knows that when water is strongly heated, steam is produced. When a thermometer is placed in boiling water at sea level, the temperature of the boiling water is found to be 212°F. or very near to this temperature. When water is boiled at high elevations, the thermometer shows that the boiling point is lower than 212°F. Speaking of his travels in Switzerland, John Tyndall, an English scientist, records: "As we ascend a mountain, the pressure of the atmosphere above us diminishes, and the boiling point of water is correspondingly lowered. On an August morning in 1859 I found the temperature of boiling water on the summit of Mont Blanc to be 184.95°F.; that is, about 27° lower than the boiling point at sea level. On August 10, 1858, the boiling point on the summit of Monte Rosa was 184.92°F. The lowering of the boiling point is about 1°F. for every 590 feet of elevation; and from the temperature at which water boils, we may approximately infer the height above sea level." Hence, from these facts we can draw but one conclusion—the boiling of water is regulated by the atmospheric pressure upon its surface. Some years ago while travelling through the mountain regions of the West, Mark Twain recorded: "We boiled our thermometers." What is the intent of this remark?

Steam and Its Relation to Water.—We already know much about steam and its uses. In our study of heating systems in Chapter VII we observed steam as a carrier of heat in steam heating systems. From experience we know that steam is used as a source of power in steam engines. These two characteristics—heat and power—make steam a very useful servant to man. Before a pound of water at 212°F. can change to steam at 212°F., 965 Btu. of heat energy must be taken up. This amount of heat, 965 Btu., which is necessary to change water to steam, is

known as the latent heat of steam. The latent heat of steam is all released when the steam is condensed. When water changes to steam under an atmospheric pressure equal to that at sea level, one cubic inch of water gives nearly 1660 cubic inches of steam; that is, one cubic inch of water gives nearly a cubic foot of steam. If water is made to boil in a closed vessel, the steam soon develops considerable pressure on the inner walls of the vessel. It is this pressure of the confined steam that requires the use of safety valves on steam cookers, steam boilers, and other devices in which steam is generated. This pressure arising from confined steam is the source of power for steam engines for the performance of work.

The Art of Distillation.—As observed in the experimental study at the opening of this chapter, we found that distillation is the process of boiling a liquid and condensing its vapor back again into a liquid. Usually when solids are dissolved in liquids, the vapor arising from the solution contains none of the dissolved materials. Thus if a solution of salt water is evaporated, the condensed vapors give pure water. The laboratory distilling apparatus usually takes the form shown in Fig. 113. The liquid to be distilled is placed in vessel *F* and heated. The vapor escapes through the tube *J*, which is surrounded by a larger tube containing cold water. The vapor condenses on the cold walls of the tube. The condensed vapors are collected in the receiving vessel *R*.

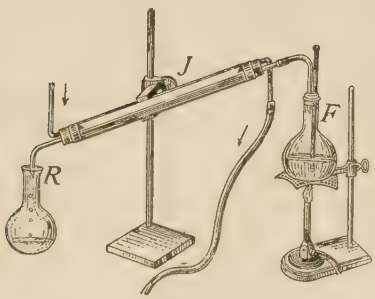


FIG. 113.—Distilling apparatus. (*From Tower, Smith, Turton and Cope's Physics.*)

Distillation is used for two purposes: (*a*) to remove dissolved and suspended impurities from a liquid, and (*b*) to separate two or more liquids having different boiling points. In the case of the two liquids, the one having the lower boiling point will be vaporized first. When a mixture of water and alcohol is placed in a vessel, *F*, the first portions of condensed vapors are largely alcohol with some water that vaporized

along with the alcohol. If the alcohol is again distilled, we find that the first portions are richer in alcohol than those obtained in the first distillation. When this process is repeated, the alcohol becomes more and more pure. This process of separating two liquids is called *fractional distillation.*

Gasoline and kerosene are distilled from crude petroleum by means of fractional distillation. In great dairy districts the milk is evaporated in order to get the solid materials. In this case the art of distillation is employed to get the solid materials free from the water in which they are suspended or dissolved.

Projects

To the pupil. In working out these projects and those in the following chapters proceed as independently as possible. Look for information in books on physics, chemistry, and engineering; in magazines, reports, and bulletins; in references listed in card indexes of libraries and in the reader's guide. Consult men who are in a position to give accurate information. Have your teacher or your parents make arrangements to visit plants and institutions where scientific principles may be observed in operation.

1. To make a study of freezing mixtures, and to demonstrate the conditions under which one or two mixtures produce the best results.

Tabulate your results as follows:

Mixtures	Quantity	Temperature
1. Crushed ice with salt	2:1	−18°C.
2. Crushed ice with sal-ammoniac	4:1	?
3. Crushed ice with calcium chloride	?	?
4. ?	?	?
5. ?	?	?

2. To make a visit to an ice plant in order to learn the principles involved in the manufacture of artificial ice.

Make a systematic report covering sources of power; units of machinery—steam boiler, steam engine, compressor, compression coils, expansion coils, appliances for handling ice cans and ice, etc.; brine tanks; temperatures; quantity of ice manufactured per day.

3. To make a visit to a cold storage plant in order to learn the nature and kinds of foods kept in storage.

Are meats, eggs, and fruits kept at the same temperature? Are the packages stamped showing the date of entry to the cold storage plant?

4. To write a short theme on one of the following subjects:

(*a*) The influence of ice plants on our modern ways of living.
(*b*) Artificial ice versus natural ice, their advantages and disadvantages.
(*c*) Cold storage plants a necessity to the present day manner of living.
(*d*) Uses and misuses arising from the cold storage of foods.
(*e*) High cost of living and cold storage foods.
(*f*) The use of ice in the home.
(*g*) The necessity of government inspection of cold storage foods and plants.
(*h*) The laws relating to cold storage of meats, fish, and poultry.

5. To make a study of the principles underlying the operation of the cryophorus in order to demonstrate the freezing of water by its own evaporation.

6. To make a study of the principles underlying the operation of a palm glass—Franklin's experiment—in order to demonstrate the boiling point of water under lowered pressure.

7. To make a study of the purity of artificial and natural ice. Prepare Petri dishes and culture media as directed in Chapter XI.

8. To investigate the principles involved in the use of pressure cookers and to demonstrate a commercial form of pressure cooker.

9. To make a study of the art of distillation as applied in the oil industry for the refining of the many varieties of oil from crude petroleum.

CHAPTER XIII

THE SOURCE AND WORK OF RUNNING WATER

Object.—To make a study of the sources of water that are available to the needs of man.

To make a study of the work of running water—the tearing down of highlands and the building up of lowlands.

The Necessity of Never Failing Sources of Water.—The winds of the earth's atmosphere are the burden bearers that are continually collecting, transporting, and distributing great quantities of water. The water which has been raised in the form of water vapor by the sun's heat energy that acts upon the surface of the oceans, lakes, rivers, and leaves of plants in forest and plain, returns in the form of rain, or snow, or ice. Where the rainfall is great, we see great torrents of water rushing down mountain sides, flowing through stream and river channels, or falling over precipices on their return trip to the ocean.

While much of the rainfall courses down rivers or evaporates back into the air, large quantities sink into the soil and increase the stores of underground waters. The underground waters supply the roots of plants, the springs of streams and rivers, and the wells of homes. In various places we observe natural barriers that hold back or retain huge supplies of water in the form of fresh water lakes and inland seas. In other places we see snow-covered mountains or highland valleys filled with glacial ice. These natural storages of liquid and solid water are being designed into the plans of man, who seeks to make life more certain and convenient.

In the earlier history of the United States, when the sparse population was occupied mainly with agricultural activities and the industrial pursuits were few, there was enough water and plenty to spare. There was no great difficulty in the way of procuring sufficient quantities of drinking water, nor was there any interference of one community with another through

pollution caused by discharging into rivers and lakes great quantities of sewage and industrial wastes. These early conditions have long since passed. Great manufacturing centers have grown up and have gathered together such large numbers of humanity that the problem of obtaining adequate supplies of water has become more and more pressing. And so today pipe lines run from mountain lakes to cities far down the valley. Walls and dams convert deep river channels into great reservoirs for the purpose of water storage. In short, man is concerned with the problems of water storage and water conservation on a scale never before known.

Furthermore, since the value set upon human life becomes higher with each succeeding period, more attention is being given to human comfort and human welfare. But greater values are secured only by constantly making improvements in those factors that contribute to pure air, to pure water, and to pure food. In order, then, that we may be better able to do our parts more wisely and effectively in the great social organization in which we live and act, this portion of our study is directed to problems concerned with water storage and the work of running water.

HOW WATER RISES IN SOILS

(Demonstration by student group No. I)

Object.—To make a study of the conditions that enable water to rise in soils.

APPARATUS.—Two or more beakers. Glass tubing of varying diameters. Bunsen burner. Five lamp chimneys or wide mouth bottles with bottoms cut off. Flat pan or pie plate. Twine.

MATERIALS.—Red ink. Strip of cloth or lamp wick. Glazed paper. Piece of unglazed pottery. White blotting paper. Gravel, coarse sand, fine sand, clay, and rich loam. Needle. Strip of card board.

PROCEDURE.—During a regular laboratory period assemble and try out all of the indicated procedures and make the customary observations. Have your apparatus assembled and materials ready for demonstration before the class at a time assigned by the instructor.

1. Have the instructor demonstrate to you the proper way of heating and drawing glass tubes to smaller diameters.

2. Draw out *capillary*—hair-like—tubes of different sizes.

3. When the tubes are cool, cut the tubes into 6-inch lengths by cutting a mark with a triangular file and snapping the glass at the point cut with the file.

4. Assort the tubes according to size—from smallest diameter to largest.

5. Select a piece of card board 2 × 6 inches and with a needle punch holes at equal intervals.

6. Pass a capillary tube through each hole in the card board and level the tops and bottoms of the tubes.

7. Set the cardboard over a beaker so that the long ends of the tubes project into the beaker as shown in Fig. 114.

8. Pour strongly colored water into the beaker until the level of the water is just above the bottom of the tubes.

9. Observe the results.

(*a*) In which tube does the colored water stand the highest? The lowest? The rise of water in the tubes and small porous spaces is due to capillary attraction.

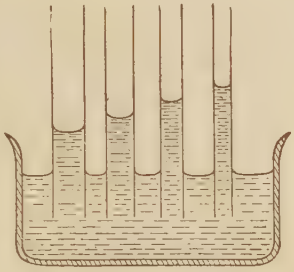


FIG. 114.—Capillary attraction in tubes. (*From Tower, Smith, Turton, and Cope's Physics.*)

10. Place a piece of card board over the top of the second beaker and suspend a narrow strip of cloth so as nearly to touch the bottom of the beaker. Suspend a narrow strip of blotting paper, a narrow strip of glazed or polished paper, a piece of unglazed pottery (a narrow piece selected from a broken flower pot), a strip of wood, and a strip of glass. Adjust the strips until they hang at the same level from the bottom.

11. Pour colored water into the beaker until the liquid touches or reaches above the level of the ends of the strips.

12. Observe the results. Account for the variance in height. Which materials are porous and which nonporous? Does the liquid climb up *porous* materials better than *nonporous* materials? Does capillary attraction act in porous or in nonporous materials?

13. Cover with a layer of cloth the base of each lamp chimney or bottomless wide mouth bottle, and bind the cloth firmly at the lower edges with twine.

14. Set the chimneys upright in a pie plate or shallow pan.

15. Place in the first lamp chimney five or six inches of gravel; in the second, coarse sand; in the third, fine sand; in the fourth, clay; and the fifth, loam.

16. Pour a quantity of water into the pan and observe the height to which the water ascends in the various soil materials within the chimneys.

17. Record your observations and conclusions regarding soils that allow capillary action to raise water within their structures.

18. Make a list of other instances of capillary action—wetting of towels, pen points, etc.

SOILS AND SOLUBLE SALTS

(Demonstration by student group No. II)

Object.—To examine soils for soluble salts.

APPARATUS.—Two beakers. Filter funnel. Watch glass. Iron ring stand. Bunsen burner.

MATERIALS.—Absorbent cotton. Clay soil. Black soil or loam. Red and blue litmus. Table salt. Baking soda.

PROCEDURE.—1. Fill one of the beakers one-third full of water and heat to boiling. Add about one tablespoonful of clay. Stir well and filter through a filter funnel lined with a layer of absorbent cotton. Place a large drop of the water on the watch glass and allow the water to evaporate.

When the drop of water has evaporated, observe the white spot that remains. This white spot is made up of salt materials that were dissolved out of the clay by the water.

2. Repeat with loam.

3. Repeat with sand.

4. Mix a small quantity of table salt with some loam and repeat the experiment. Did the table salt dissolve out and go through the filter with the water? Does water rob soils of soluble salts? Where do rivers carry all the soluble salts of the world? When water evaporates, what becomes of the dissolved salts?

5. Mix a small quantity of baking soda with some soil and repeat. Test with red litmus. Test with blue litmus.

Litmus turns blue or deeper blue when alkalies are present; red or a deeper red when acids are present.

Does baking soda make soils acid or alkali?

Filter and test with litmus the water that passes through. Is the water acid or alkali when tested with litmus?

Does water passing through soils dissolve and carry away alkalies? What becomes of these alkalies?

THE WORK OF RUNNING WATER

(Demonstration by student group No. III)

Object.—To observe the action of running water upon the various kinds of soils.

APPARATUS.—Long shallow pan. Sprinkling can.

MATERIALS.—Gravel. Coarse sand. Fine sand. Clay. Loam. Water.

PROCEDURE.—1. Mix equal quantities of gravel, coarse sand, fine sand, clay, and loam.

2. Punch one or more holes near the bottom and at one end of the pan and pile the mixed soils in the other end.

3. Sprinkle water steadily onto the pile of mixed soils.

4. Allow the water to drain out into a glass vessel and tilt the pan in order to drain off the water.

OBSERVATIONS.—1. Is there much fine material suspended in the water that has drained off?

2. Has fine soil settled in the far end of the pan—the *flood plane*?

3. Where are the coarse materials?

4. Where are the gravel particles?

5. What is the appearance of the surface of the soil pile upon which the water was sprinkled? Are there *erosion* effects?

6. Will rains do greater damage to cultivated fields or to grass covered fields? Explain.

7. Are heavy rains or light rains of longer duration more beneficial to cultivated lands? Explain.

A STUDY OF SOILS, ROCKS, AND EROSION EFFECTS. (A FIELD TRIP)

Object.—To plan a trip to a nearby country district where cultivated fields, meadow lands, woodlands, hillsides with rock and clay exposures, and a small stream may be observed and studied.

PROCEDURE.—(*a*) Cultivated fields. Observe whether the surface of the field is *level* or *rolling*. What is the color of the soil? What is the nature of the crop? Does the surface of the field show effects caused by the "run off" of rain waters? Where did the running waters deposit or drop the soils? Are the top lands and hillsides robbed of their best soils by the flowing rain waters?

Examine one of the small hillside ditches. Where does water enter the ditch during rain storms? Is there a flood plane at the lower end of the ditch where the flood waters deposit soils? Is a new layer of soil deposited over the flood plane every time it rains? Examine the soil layers exposed on the walls of the ditch, and observe the position of the loam and clays. Are there rocks and pebbles in the bottom of the ditch?

(*b*) Meadow land. Is the surface free of water erosion? Does the surface show greater or fewer erosion effects than if the same surface were cultivated? Why is this so? Do grass lands hinder or aid erosion effects on the part of running water? Where is the grass crop most abundant—in the lowland or the highland portions of the meadow? Give your reasons for this.

(*c*) Woodlands. Compare the texture of the soils found here with those observed in the cultivated and meadow areas. Are there areas in which the trees are larger and more vigorous than in others?

Compare the erosion effects with those observed in the cultivated and meadow areas. If the forest is located on a hillside, can you imagine the erosion effects that would take place were the trees removed? Do the same trees grow in highlands of the forest as in the lowlands? If the highlands and lowlands are not extreme you may find the same trees in each locality. What becomes of the annual crop of leaves that fall from the

trees? Examine the soil beneath the trees and see if you can find the remains of decaying leaves. What is leaf mold? Is it full of plant food? Does leaf mold hold moisture better than sand? Does leaf mold allow water to "run off" as rapidly as does a surface of clay? Give two uses of the bed of leaf mold to the forest trees.

(*d*) Hillside with exposures of rock and clay. Do the exposed rocks run in layers? Are the layers horizontal or vertical? Does the stratified rock indicate that they were once the bed of an ancient ocean? Reason. Observe the thickness of the various layers. Is there a layer of fine clays between the rock layers?

Do you find fossil remains in the rocks or on their surface? Examine the rocks carefully and discover whether some are softer than others. Do you observe a quantity of loose rock at the foot of the rock exposure or rock ledge? What forces loosened these rocks and caused them to fall to the foot of the rock ledge?

Do you observe rocks that seem to be crumbling and weathering away? Do the rains carry away the crumbling portions of rocks? What becomes of the soluble plant foods that were locked up in the crumbling rocks? Are crumbling rocks a source of clay soils and plant foods?

Do the winds and rains that act on the whole face of the rock exposure loosen and carry soil materials? What other weathering forces—heat, frost, roots of plants, etc.—do you observe at work on the rock surfaces?

(*e*) The small stream. If you are near the head of the stream make a study of its source. Observe whether there are one or more springs that serve as the source. Whence come the spring waters? Before the water makes its appearance in the spring, it is commonly called ground water or *underground water*. Whence come the waters that provide the underground supplies?.

As you go down stream observe the channel through which the stream flows. Is the channel bed composed of dirt and sand or of smooth rock surfaces? Are there deep pools and small rapids? What conditions exist to produce rapids? Are loose rocks found along the banks and stream bed? Are they sharp and rough, or rounded and smooth?

Are the waters of the stream dark and full of suspended soil materials or are they clear? Where is *sediment* dropped, in the deep pools where the water is slow moving or at the rapids where the water moves more rapidly? Is the stream carrying soil materials from the highlands to the lowlands?

At what season does the stream overflow its banks? Are there any indications of recent floods? Have the flood waters deposited mud and rocks on either bank of the stream? Whence came the materials carried down stream by the flood waters? In short, what is the work of streams?

(*f*) Report your field trip in the form of a report that is made up of five well-written paragraphs:

(*a*) The soils and erosion effects observed in a cultivated field.
(*b*) Same as (*a*) for meadow.
(*c*) Same as (*a*) for forest.
(*d*) Same as (*a*) for rocky exposure.
(*e*) Same as (*a*) for the stream.

The report should summarize the information obtained on each of the above topics.

Precipitation, the Source of Land Waters.—Snow, sleet, and rain are closely related forms of condensed and precipitated water vapor. As soon as the water strikes the ground it is disposed of in three ways: (*a*) by evaporation, (*b*) by running down the slopes of the land to streams, and (*c*) by sinking underground. The proportions disposed of in any of the three ways vary greatly under different conditions. The greater part of a light and long-continued rain may run in and pass underground, especially if falling on a grass or forest plain. A heavy rain falling on steep slopes is largely disposed of by direct run-off. In hot and arid regions the great portion of rainfall "flies back" or returns as water vapor to the atmosphere. Indeed, instances have been observed in which rain falling from clouds has failed to reach the surface of the earth on account of the evaporation taking place while the drops of rain were passing through the hot layers of air that lie above the arid regions.

Evaporation and Its Relation to Water Supply.—Much has already been said about evaporation, its relation to our comfort and health, and the conditions governing its rate of action. While we recognize that there is such a process at work delivering supplies of moisture to the passing air currents, we seldom realize the powerful influences and conditions that are solely due to evaporation. Everybody realizes the work of a rainstorm, yet few ever think that the rainstorm, snowstorm, and great cloud masses had their beginning in processes solely concerned with evaporation. Evaporation is at work day and night throughout the year. This process of water removal is constantly robbing water from lakes, rivers, animals, and all things that contain it.

The condition of the surface of the ground determines largely the amount of water that returns to the air by evaporation. When the surface of the soil is open and porous, or covered with

plant life, the rain waters are enabled to sink into the ground and saturate the under layers of soil and subsoils. If the plant life is absent or scarce and the surface of the soil hard and firmly packed, the water is then prevented from soaking into the ground; and consequently the run-off is greatly increased. The waters that pass to the underground are preserved from the influence of evaporation processes, but those of the run-off are continually losing water vapor from their surfaces. After a good deal of study, investigators have determined that direct evaporation from oceans supplies the water vapor for three-fourths of the total rainfall, while that from inland waters and land surfaces supplies the other one-fourth.

The Storage of Ground Waters. Wells; Artesian Wells; Springs.—As already stated, a portion of the rainfall sinks into the ground. The quantity varies with porosity of the soil, the steepness of the sloping surfaces, and the covering of vegetation. Fine clay and compact limestone absorb water, but allow very little to pass through. While loose soils, sand, and coarse sandstone do not absorb as readily as clay, these materials allow water to pass through quite freely.

Near the top of a porous soil the moisture sinks quite rapidly; but as it descends the soil becomes more and more compact, and consequently the water is forced to sink more slowly. Finally the water reaches a level where it begins to accumulate and stand at a certain level known as the *water table*. When the rains are heavy and more or less continuous, the water table slowly rises. During seasons of little rain or prolonged drought the water table gradually lowers. If a well is sunk to a depth below the level of the water table, water will rise in the well to a level no higher than that of the water table. When the level of the water table is above any part of the surface, springs occur; and when the water table sinks below the surface level, springs "dry up."

The passage of ground water from place to place is controlled or influenced by the soil and rock structures of the earth. Sandstones have considerable space between their grains, but their porosity varies greatly with the size of the particles and the cementing materials that hold the particles together.

Limestones are only slightly porous, while clay, shale, and slate are so nonporous that they are impervious to the passage of ground water.

When, in the course of their travels, ground waters become trapped in a porous layer or stratum of rock that is confined between two impervious layers of rock, storage of underground

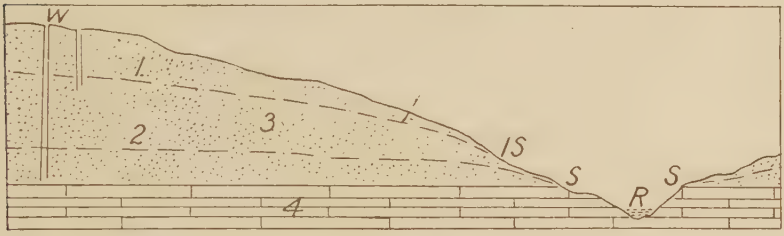


FIG. 115.—(1) Water table during wet seasons. (2) Water table during dry seasons. (3) Porous soil and gravel. (4) Nonporous layers of rock. (*IS*) Intermittent spring. (*S*) Spring. (*W*) Wells, one of which will have an intermittent supply of water. (*R*) River or small stream.

waters is the result. Often the conditions of water storage are such as to place the water under considerable pressure, especially when the impervious rock layers that confine the water are inclined as shown in Fig. 116. The rainfall at *AA* sinks

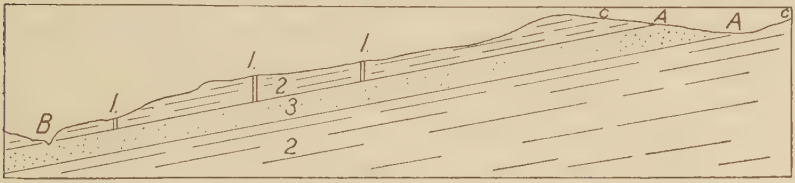


FIG. 116.—The rainfall in the artesian basin, *CC*, sinks into the ground as it flows into the area *AA* and becomes entrapped between the impervious layers (2) that confine the porous stratum (3). Continuously flowing springs occur when erosion processes work through the upper impervious layer (as shown at *B*) and when the artesian basin, *CC*, is of great extent. (1) Artesian wells.

under ground and finally becomes entrapped between the two impervious layers that confine the porous stratum. If holes are bored through the top layers of clay and the impervious rock layers, the water will rise to the level of the water table. When the top opening of the hole is below the water table, the water gushes forth in a fountain-like manner, giving what is commonly called an *artesian* or *flowing well*. The basin in which the water

is stored is known as an *artesian basin*. When the water flows forth from an artesian basin of great extent, shown at *B*, we have conditions that are ideal for continuous flowing springs. Such springs often give rise to streams that serve as the head waters of river systems.

Quantity and Quality of Ground Waters.—The quantity of ground water is exceedingly variable with the region and with the season. When the artesian basin is large and is so placed that it receives great quantities of rains and melted snows, the volume of the water is large and the supply continuous and uniform. Eastern South Dakota lies over a great artesian basin in which there are many artesian wells yielding all the way from 300 to 3500 gallons per minute.

Since ground waters are always in close contact with rock materials through which they percolate, they contain varying amounts and kinds of mineral substances in solution. Since sand, gravel, and limestone contain few soluble materials, the ground waters that are stored in them are known for their purity. In other instances, where the ground waters are brought into contact with salt beds, or calcium and magnesium compounds, or iron salts, we have waters that are unsuitable for some domestic and industrial uses. But, in general, they are of a high degree of purity. When protected from surface waters, which are usually contaminated, ground waters are absolutely free from filth that bears bacterial diseases.

The Work of Ground Water.—For countless ages the ground waters have been at work dissolving and thus removing portions of the rock materials through which they circulate. While the dissolved amounts for any short period of time are very small, the total throughout the ages is exceedingly large. As a result we find tunnels, caves, and caverns hollowed out beneath the ground surface. In many cases the tunnel or cavern roof has fallen in, and thus the cavern or tunnel has changed into a valley in which weathering and erosion continued the work. In this way the work of ground waters prepares the rock structures for more rapid attack by surface agents, and thus takes an important part in the tearing down and removal of soils.

The Run-off.—That portion of the rainfall that neither evaporates back into the air, nor sinks into the ground, but simply flows from the surface of the ground in rills to form brooks and streams, is called the run-off. In short, the run-off is what is left—the remainder—after evaporation and ground absorption have had their share. It is the run-off that damages the surface of cultivated fields, that produces extremes of river flow, that causes floods which destroy life and property. The run-off is that portion of the rainfall which man seeks to put to better and more complete use, that portion which he hopes to store and control and direct to the service of human needs.

Many regions of the earth have extremes of rainfall and drought. In order to level these extremes, it is the purpose of man to find means of storing the excess of rainfall of the rainy season in order that the stored-up waters may be distributed during the periods of drought. Irrigation ditches will conduct the stored-up excess rainfall of one district into another district in which there is little rainfall for the development of essential food crops. Furthermore, the stored-up waters in order to gain their release will be forced to turn water wheels and water turbines and thus drive machines in the performance of work.

Erosion, the Work of Running Water.—During a downpour of rain, particles of soils are loosened and carried away in the run-off. When the downpour is heavy, pebbles and stones are pushed and rolled to lower levels on the hillside or carried farther down the valleys through which the flood waters flow. The soluble salts of the soil go into solution and disappear with the run-off. The finer particles of soil become suspended and give flood waters their murky appearance. The soluble salts remain in the water on its passage to the seas and oceans. The fine particles are held in suspension and settle out as mud and silt in the lowlands, where the run-off moves more slowly than when passing through the narrow and steeper portions of the upper valleys. In short, the run-off is at work tearing down the highlands and building up the lowlands—removing the soils and salts that serve as plant foods on the highland farm to the farm of the lowland.

The successful farmer or land owner is continually devising means and methods for preventing the formation of rills and

ditches in the surface of his cultivated fields. The steep sidehills are planted with grasses, the roots of which bind the soils and thus prevent the erosion effects that would take

FIG. 117.—An eroded surface. (*Courtesy of U. S. Forest Service.*)

place were the hillside bearing a cultivated crop. The lower areas of the cultivated fields, where the water flows during a heavy downpour, is left as grass land from which hay may be prepared. Woodlands that grow upon rocky slopes and other

low grade lands are never completely removed. Only the mature trees are cut and utilized, but the young and immature are left for growth and development and future needs. Many other means are employed to lessen or prevent the erosion effects of running waters, but from the standpoint of the farmer and land owner the roots of grasses and trees provide the best protection.

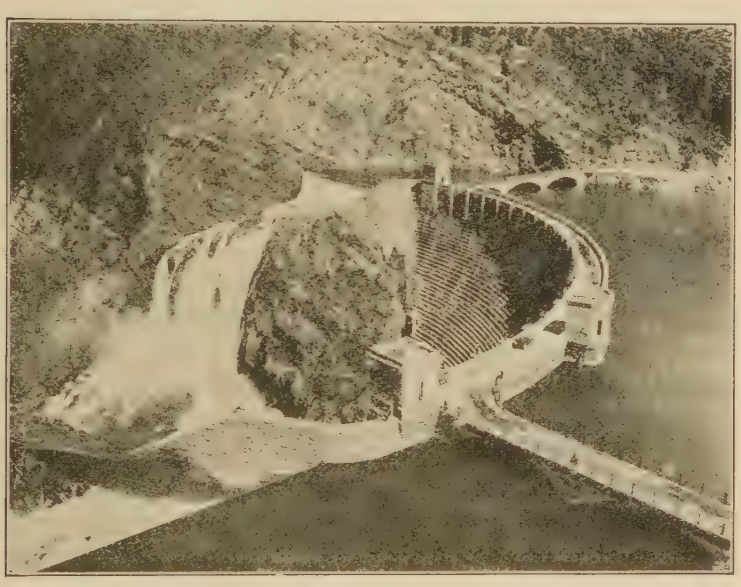


FIG. 118.—The Roosevelt Dam on Salt River, Arizona, is 280 feet high. It has a storage capacity sufficient to cover with water 1,367,000 acres one foot deep. Below the dam, and out of sight in the picture, is a power-house capable of developing 7500 horsepower. (*From Brownell's General Science.*)

The Storage of the Run-off.—Among the oldest movements concerned with labors of man are his works concerned with water supply. In Egypt a large depression in the desert near the Nile river was utilized in ancient times as a natural reservoir for the storage of the flood waters of the Nile. Some historians and engineers believe that these storage waters were used to keep the waters of the Nile at a level sufficient to keep the irrigated lands well watered for a greater length of time. Thus the flood waters, instead of being allowed to escape, were stored and utilized for the greater development of food producing

crops. Rome received through massive aqueducts the cold waters of lakes and streams located in the distant mountains.

Today in the western part of the United States, there are many similar conditions where reservoirs may be constructed not only at the head waters of streams but at points far down mountain valleys. In Southern California and just to the west of the Colorado river lies a great depression, Imperial valley, that extends 250 feet below the level of the sea, and corresponds in many ways to the desert depressions that lie to the west of the Nile in Egypt. Already the Imperial Valley receives irrigation waters from the Colorado river, and greater development is only dependent upon the possibility of greater water storages to carry over during the years in which there is drought, or to prevent floods from producing disaster and ruin in years of heavy rainfall.

Mountain lakes have long been recognized as one of the best sources of pure water. In order to obtain the water from these natural reservoirs, a pipe line or an aqueduct is the only requirement. In the Sierra Nevada Mountains on the boundary of California and Nevada lies Lake Tahoe. This mountain lake represents ideal conditions for mountain storage, for, by building a dam across the narrow outlet, its storage capacity has been increased with very little cost. When not located at too great a distance, mountain lakes are one of the best means of water storage for cities and are always a convenient source of water for power and irrigation purposes.

As the rivers descend from their head waters located in the highlands, they are joined by other small rivers and streams, and thus their volumes of water become greatly increased. The possibility of creating water storages in the plains through which these great volumes of water pass depends upon the existence of a suitable site for dams and reservoirs. In some instances suitable sites are wholly lacking, and little can be accomplished in the way of water storages.

The Great Lakes, Storage Basins of the St. Lawrence.—The Great Lakes, that form a portion of the natural boundary between the United States and Canada, are the largest natural fresh water storages in the world. In this region a considerable

fall of rain and snow keeps these great reservoirs constantly supplied. The natural outlet of this vast store of water is the St. Lawrence river. In respect to floods the St. Lawrence with its five great lakes stands in strong contrast to the Ohio river, which is without lakes.

The St. Lawrence has no great floods, because no rain is heavy enough to raise the surface of the lakes over a very small amount, and hence the outflow of the river cannot be greatly increased in volume. The rains and spring thaws of the upper Ohio basin are not collected in lakes, but flow quickly down the hillsides to many small streams that promptly empty their flood waters into the Ohio river. Consequently floods in the Ohio valley may rise fifty or sixty feet in a few days. These floods spread out over ten to twenty times the ordinary width of the river, and thus great damage is done to life and property in the villages and cities situated on the floor of the valley. Wherever lakes occur in the course of a stream, they act not only as natural reservoirs for water storage but as regulators of the discharge of the run-off in out-flowing rivers. Furthermore, in the case of the Great Lakes we find that before the waters of Lake Erie can enter Lake Ontario they plunge over Niagara Falls. Here the lake waters serve as a source of power for producing electricity that drives machinery and lights cities located many miles distant.

Forests Conserve Water and Soil.—Whether or not greater rainfall results from the presence of forests, it is fairly well established that the forests tend to conserve the waters that fall upon the forest bed. The necessary conditions for water storage are rendered more satisfactorily where forests are present than where the mountain slopes are bare of forest coverings. In the irrigated regions of the west nearly every community is demanding that the forests at the headwaters of streams be better protected. So strong is the belief concerning forests and their close relationship to water conservation that the United States is purchasing large tracts of forest lands at the headwaters of navigable rivers in the Appalachian regions of the south and the White Mountain region of the north. The forests not only conserve the supply of headwaters, but prevent the rapid erosion

and washing of the soil from the mountain slopes. The soil carried away is not only lost to the mountain slope and valley, but, more than this, is a real injury in the way of filling lakes, reservoirs, river channels, and the harbors of navigable waters.

The degree of civilization of a group of people is shown in the way in which they make provision for future generations. A man who is willing to plant trees which will yield harvests of fruits and nuts, not during the remaining years of his life, but in those of his sons and grandsons, displays an interest in human welfare not shown by the man who is concerned only with his daily needs. Likewise nations show their true development by the provision that they make for the prosperity, health, comfort, and happiness of future generations. In the many problems of reconstruction and conservation, the forests take a very effective place. The forest supplies that are being used today were developed in the ages of the past. If, then, the future generations of men are to share the good things which we now enjoy, it is our duty to conserve, reconstruct, and hand on to others in better condition those things so necessary to a successful people.

Projects

1. To make a study of the conditions that lead to the formation of one of the following:

(*a*) The Great Lakes and the basin of the St. Lawrence River.

(*b*) The Grand Canyon of the Colorado River.

(*c*) The Valley of the Red River. (Usually given in accounts of Agassiz's life and work in connection with Agassiz's Lake.)

2. To make a study of the conditions that give rise to the formation of glaciers.

3. To become acquainted with work undertaken by the United States government relative to the conservation of forests and reclamation of forest lands.

4. To become acquainted with the methods employed in the reclamation of arid lands.

5. To make a study of the rock formation in the neighborhood of the community in order to become acquainted with conditions that led to the formations.

6. To make a collection of the fossils that occur in the rock and soil layers of the community and to exchange specimens with other pupils throughout the United States.

Suggestion.—Display in appropriate cases, and properly labeled, all specimens collected and received in exchange.

7. To collect and to display the mineral ores of the community, the county, and the state. (Exchange with pupils in other regions throughout the United States.)

8. To make a map that shows the rainfall for the various regions throughout the United States in order to set forth the relationship of rainfall to the nature and amount of crop production for each of the regions.

9. To make a study of the conditions that led to the building of Roosevelt Dam, and of the resulting importance of the dam since its completion.

10. To make a study of weathering processes and their relation to plant life.

11. To become acquainted with the conditions that give rise to underground storages of water and their relation to farming activities.

12. To become acquainted with the conditions that give rise to floods, and with the means that may be used to prevent or regulate them.

CHAPTER XIV

WATER AND ITS RELATION TO HEALTH PROBLEMS

Object.—To make a study of those problems of health that arise from conditions concerned with water.

Life and Health Dependent upon Water.—Without water all the living organisms of the earth would cease to exist as such. The body of every living form is composed largely of water. Within these living forms the presence of water is necessary to the processes of growth and repair and for the removal of waste materials. Hence the first and most important use of water to mankind is for drinking purposes. Furthermore, continued health is dependent upon having sufficient supplies of water of a high degree of purity, especially water not contaminated with vegetable and animal waste. Without pure water a community is subject to lower health conditions, and with water occasionally contaminated with bacterial waste there is constant danger of typhoid and intestinal diseases.

Cities and villages that have constant supplies of pure water attract people from places in which there are constant disease dangers arising from polluted water supplies. Poor water gives the worst kind of reputation to a city or community, for it advertises the community as thriftless, shiftless, and thoughtless of the value of human life. Today, public health is a purchasable commodity. That is, if a community is willing to raise money to make improvements in the quality of water supplied to its inhabitants, the public health of the community is raised, happiness and comfort are more general, and the efficiency of its citizens is increased. And so today progressive communities, large and small, are supplying adequate quantities of water which is reasonably clear, odorless, and tasteless, and free from contamination by sewage or industrial wastes. Notable among cities that have constructed extensive and costly systems for the procuring and distributing of supplies of pure

water are New York and Los Angeles. In the case of New York it was necessary to purchase large tracts of lands near the head waters of small streams located in the distant Catskill mountains. The city of Los Angeles brings its water supply from Owens Valley in the Sierras, a distance of 240 miles.

WATER AND MICROSCOPIC FORMS OF LIFE

Object.—To make a study of those conditions necessary for the development and growth of the lower forms of life.

To observe and identify by means of the compound microscope one or more of the simple forms of life that live and work in water.

Apparatus.—Microscope. Slides. Cover glasses. Medicine dropper.

Materials.—Three Mason jars. Hay or dried swamp grass. Distilled water. One per cent solution of formaldehyde. Acetic acid. Salt. Sugar. Solution of quinine.

Procedure and Observations.—1. Number the jars #1, #2, #3.

In jar #1 place distilled water.

In jar #2 place distilled water, a small bundle of loose hay or dried swamp grass, and a few drops of formaldehyde.

In jar #3 place some distilled water and loose hay or dried swamp grass.

Set the jars aside in a warm place.

2. After two or three days observe the surfaces and the color of the liquids. What differences do you observe? Are there odors present? In which jar are the processes of putrefaction and decay at work?

3. Have your instructor show you how to remove and examine drops of water from the surface of the liquids, and how to examine them by means of the compound microscope.

Examine various drops from each of the jars. Examine drops taken from the surface of and deeper in the liquid. In which jar do you find signs of life, minute organisms—bacteria? Do you observe any swimming forms? In which jar do you find them? Can you see any reasons for this? Are there any food materials for the organisms in distilled water? Does formaldehyde prevent the development of the *bacterial organisms?* Does the hay in jar #3 serve as food for these microscopic forms? When ponds dry up, the microscopic organisms transform themselves into very minute egg-cells or spores. These dormant or inactive forms are carried by the winds and deposited. Those on the hay were awakened into the active state when the hay was placed in the jars of water. Examine the jars every four or five days according to directions that follow.

4. The large slipper-shaped forms that move about quickly are *paramecia.* See Fig. 120. This is an enlarged drawing of the paramecium and shows its simple structure. While observing the moving forms

under the microscope, see if you can distinguish between the inner mass of *protoplasm* (*endosarc*) and the outer layer (*ectosarc*). Which appears the more firm and gives shape to the body? Which is the more clear and transparent?

5. Can you distinguish an *anterior* (foremost) from a *posterior* end?

6. Do the paramecia avoid objects? While in motion do they collide with each other? Set this slide aside and examine it under the microscope at the end of the period. Are the paramecia as active at the end as at the beginning of the period?

7. Are paramecia sensitive to external influences? To find out, place a single grain of salt near the edge of the cover glass so as to touch the water underneath. What is the result? Watch the individual paramecia as they move into that part which contains the salt solution.

On a new drop containing paramecia try a minute drop of acetic acid applied with a capillary tube. Compare results with those of salt.

Try sugar. Quinine. Are the paramecia sensitive to external dangers? Explain.

8. Using the high power of the compound microscope, make a careful examination of a paramecium. Do you find any hair-like bodies protruding from the cell wall—ectosarc? These hair-like filaments are called *celia*. Do the celia aid the paramecium in its movements? Do you observe a mouth-like cavity—*the gullet*—on one side of the body?

9. Paramecia are *one-celled organisms* and represent the lowest and simplest form of life known in nature. These low forms of animal life are known as *protozoa*. Other protozoans may be present in the hay-infusion.

The Vorticella, bell-shaped forms, are often found attached to scum masses taken from the surface of the water. See Fig. 121. Observe them under the microscope. Study their actions and habits and report.

Occasionally you are able to locate an *amœba*. See Fig. 122. If so, study it under the high power. Amœbas do not often occur in hay-infusions. The surest method for securing them is to chop up the soft part of two or three water mussels, placing the scraps together with shells that lie on some sand in a large shallow basin of water. Add some surface mud taken from the bottom of streams or ponds. Allow water to drip on the surface of the water in order to keep it slightly agitated and to remove great numbers of bacteria. Amœbas should occur on the surface of the water about the margin of the pan, or on the surface of the mud, or about the shells. Examine each day for several days. Many other forms will also present themselves in this preparation.

PURIFICATION OF WATER; FILTERING PROCESSES

Object.—To learn how to remove finely divided substances that remain suspended in water.

Apparatus.—Two or more bottles. Glass funnel.

MATERIALS.—Supply of lime water. Solution of ferrous (iron) sulphate. Absorbent cotton. Finely divided clay. Salt.

PROCEDURE AND OBSERVATIONS.—Fill a bottle one-half full with water and add a small quantity of finely divided clay. Shake vigorously. Allow to stand for five or more minutes. Without disturbing the settled clay, pour off (decant) the upper portions of water to a second bottle.

Is the decanted water clear or murky? If it is murky add a quantity of lime water. Now add a solution of ferrous sulphate drop by drop and observe the formation of a cloud of red substance. Continue to add drops of the ferrous sulphate until the red clouds cease to form. Now add one or more drops of lime water. Allow the contents to settle.

Has the red cloudy substance gathered all the fine particles of clay and carried them to the bottom? This method of settling and freeing water of fine suspended particles of clay—also germs—is called *coagulation*. The red clouds formed from the lime and iron sulphate solutions gathered up the particles of clay and germs and carried them along to the bottom of the jar.

Line a funnel with an even layer of absorbent cotton. There should be no holes in the layer of cotton. Carefully moisten the cotton and see that it sticks everywhere to the funnel. Decant the top layers of water into the center of the cotton filter. The filtered water should be clear.

These processes of *settling*, *coagulating*, and *filtering* are used by cities and industries on a large scale to free river water of finely divided and suspended clay and bacteria. Coagulating and settling are often applied to sewage products before they are allowed to enter rivers that bear away sewage waters. In the place of cotton, layers of small pebbles covered with a layer of fine sand serve as filtering beds.

MOSQUITOES AND WATER (DEMONSTRATION CARRIED OUT BY TWO OR MORE STUDENTS)

Object.—To make a study of the life history of the mosquito in order to determine its relation to water.

To find means of exterminating mosquitoes from the bodies of water in which their forms occur.

MATERIALS.—Three battery or Mason jars.

PROCEDURE AND OBSERVATION.—Fill the jars one-half full of rain or tap water. Set them aside in some tall grass or flower beds where mosquitoes find a roosting place. Observe daily for the presence of rafts of eggs floating on the surface. Hold the jars up to the light and observe the water for the presence of "wrigglers."

When eggs or "wrigglers" have been discovered, carry the jar to the class room for further examination and study.

Place wire screens over the mouths of the jars.

Allow the mosquitoes in jar one to go through all the stages of development.

Place kerosene or crude petroleum on the surface of the water in the second jar when the wrigglers have hatched out.

Place a couple of small gold fish in the third jar.

Observe the jars from day to day and report the results.

Would there be any mosquitoes if there were no stagnant waters in which they might develop? Reasons.

Would the drainage of swamps be more effective than oiling the surface or supplying fish? Which of the three methods would be the most permanent?

Microbes; Bacteria.—"Microbes" is a name given to those living units which can only be seen by the aid of the compound microscope. They are the simplest and the most minute

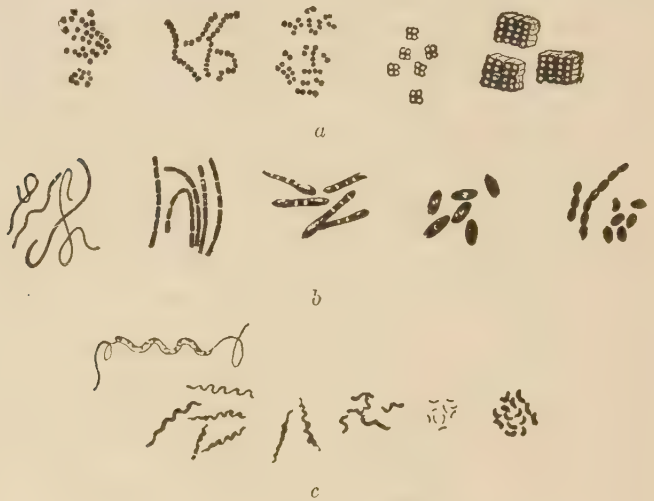


FIG. 119.—*a*, types of micrococci; *b*, types of bacilli; *c*, types of spirilla. (*From Marshall's Microbiology.*)

organisms found in nature. Some belong to the animal kingdom, others to the vegetable. The bacillus of tuberculosis and the typhoid bacillus belong to the class of *bacteria*—lower plants. The trypanosoma of sleeping sickness is a *protozoan*—lower animal. Whether animal or vegetable, almost all microbes consist of a single cell. When there are several closely collected, they are practically many individual cells closely grouped. Microbes are, of all living creatures, the most widespread. They exist wherever there is organic matter—plant and animal material—to serve as foods.

Microbes exist in two well defined states—dormant and active. The dormant or sleeping state is an inactive state which the micro-organism assumes during periods unfavorable to growth and the active processes of life. When the dormant form is surrounded by right conditions of temperature, food, moisture, and oxygen, the microbe is awakened and the processes of growth and reproduction take place. So long as one or more of these conditions are absent or unfavorable, the active processes of life within the microbe remain dormant.

In every day language the term "microbes" most frequently signifies bacteria. Bacteria are usually classified according to their form or appearance. The round bacteria are called *cocci*—ball shape. They may occur singly, or grouped in series like beads on a necklace, or in groups and clusters. The *bacilli*—rod shaped—are long bacteria having their ends rounded like a spindle or shuttle. The *spirilla*—spiral shaped—appear curved.

Bacteria Multiply by Division.—One bacterium surrounded by suitable conditions for awaking growth and development produces after a length of time two; these two produce four; and these four, in their turn, eight, and so on. It is, therefore, easy to imagine the vast numbers that may result provided proper conditions and available nourishment are present. In man the tissues of the intestinal walls, the kidneys, and the spleen provide ideal conditions for rapid growth and multiplication of the typhoid bacillus. Bacteria are usually not killed by freezing, and many kinds will endure a temperature of more than 200°F. below zero without losing their vitality. Ice may harbor the germs of many diseases and particularly typhoid bacilli, which are especially hard to kill. Boiling kills most bacteria, but the dormant or spore state of many kinds will resist even boiling for a certain period.

Bacteria are almost universally distributed in water, in all sorts of organic material, and in soils. When we remember that invisible particles of dust may be many thousand times larger than a bacillus, we can imagine how great numbers may be carried in a single particle of soil or a drop of water. Because of their minute size when in the inactive state, they are carried

to all parts of the earth by wind currents, and thus their presence may be anywhere and often everywhere.

Water and Microscopic Forms of Life.—When hay is curing in the fields and lowlands preparatory to its harvesting, the dormant spores of bacteria and protozoa are dusted upon the leaves and stocks of the drying plants. The spores remain with the hay materials and are awakened to action and growth only when the proper conditions are present. Consequently, when some hay or dried swamp grass has been allowed to stand aside in a jar of water for a period of two or three days, drops of surface water examined under a compound microscope are observed to contain great numbers of bacteria at work on the decaying masses of hay. A few days later a scum forms on the

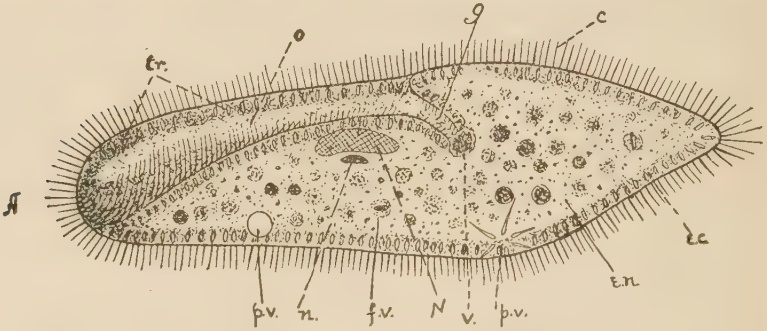


FIG. 120.—Paramecium. *A*, anterior end; *c*, cilia; *ec*, ectosarc; *f.v.*; food vacuole; *g*, gullet; *N*, micronucleus; *n*, meganucleus; *o*, oral groove leading to mouth; *p.v.*, pulsating vacuoles; *v*, food in process of formation. (*From Galloway's Zoology.*)

surface; and when drops of water are removed and examined under the microscope, large one-celled animals may be discovered feeding on the bacteria and bits of scum. These one-celled animals are known as *protozoa* and have characteristic shapes and movements that identify them. The slipper shaped forms—*paramecia*—move readily from place to place in search of food. The bell-shaped forms—*vorticella*—are attached to scum masses by means of thread-like bodies which push them out in search of food or quickly withdraw them from unfavorable conditions. Also a sluggish shapeless form—*amœba*—may be observed pushing and spreading itself in many directions at the same time.

While these simple forms consist of a single cell, they seem to be performing more or less successfully the many functions of

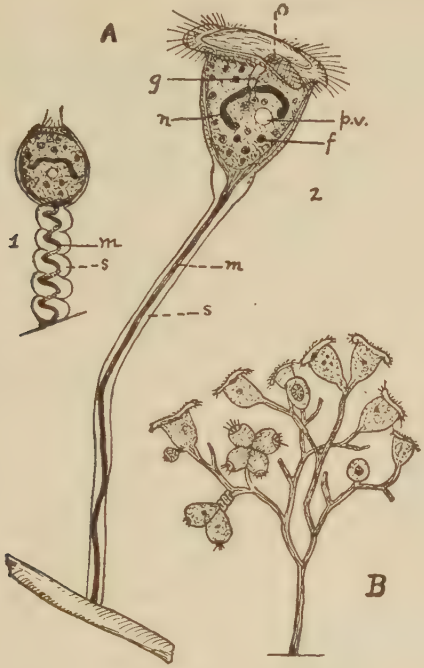


FIG. 121.—*A*, vorticella, single; *B*, colonial type; (1) contracted, (2) extended; *f*, food vacuoles; *g*, gullet; *m*, contractile fibre (muscular); *n*, nucleus, *o*, mouth surrounded by cilia; *p.v.*, pulsating vacuole; *s*, stalk. (*From Galloway's Zoology.*)

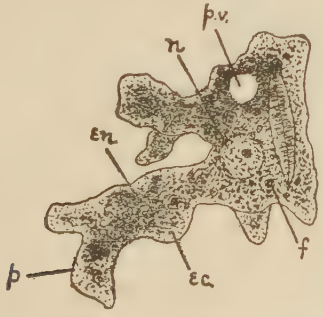


FIG. 122.—Amœba. *ec*, ectosarc; *en*, endosarc; *n*, nucleus; *p*, pseudopodium; *p.v.*, pulsating vacuole. (*From Galloway's Zoology.*)

life. They are able to move. They are able to select food materials and reject wastes. They become more and more numerous—that is, they reproduce others like themselves.

They move away from unfavorable conditions and areas of danger—that is, they seek to protect themselves. In short, they are able to perform in a simple way all the life processes necessary for a successful existence.

Primitive Methods of Procuring and Distributing Water.—In primitive life man employed the simplest possible means of securing those materials required to meet the needs of life. In many instances the people of various countries still employ these first methods brought into use by their primitive ancestors. The simplest way of getting a quantity of water is to dip it from a spring, a stream, or a lake. In tropical countries like Venezuela or India, or in Oriental countries like Persia and Arabia, women go each morning to a fountain, or a stream, or a lake and return home with the day's supply of water. In many places men with water carts or skin bags sell from door to door the polluted waters which they have gathered from a nearby stream or river. In such places little or no water is used for cleaning purposes in the home. The clothing and other materials are taken to the river and there washed. Consequently, in these countries where little or no attention is given to securing adequate supplies of pure water for drinking and cleansing purposes, disease epidemics and plagues are frequent, and the people are unprogressive.

Water Holes and Wells.—Primitive savages who lived in semi-arid regions soon learned to appreciate the needs of water storage. Consequently, where the surface clays or rock layers were impervious to water, basin-like cavities were hollowed out wherein the run-off of rain waters collected. Many natural depressions or surface-holes were sometimes found in which the run-off collected and remained until emptied by evaporation. These natural water storages were often enlarged and protected with guard walls in an attempt to insure water supplies during periods of drought or of little rainfall.

In modern life, deep and narrow holes are dug near the home dwelling. These holes are carefully lined with stone or brick and cement. The rain that drains from the roof of the home dwelling is conducted by pipes to this storage basin. Such underground storages are commonly called *cisterns*, and their

stores of water are known as *soft water*, for the reason that it contains no dissolved salts or other materials.

When a hole is sunk to a level below that of the water table of the underground waters, the water seeps—percolates—into the sunken hole, filling it to the level of the water table. Holes that thus receive their supplies of water from underground storages are used as wells and may serve as such, so long as the water table remains above the bottom of the hole. Well waters usually contain in solution varying amounts of calcium and magnesium salts collected from the soil and rocks through which they have percolated. Such waters are known as *hard water*.

Dangers Arising from the Use of Wells and Cisterns.—Often the surface openings of cisterns and wells are not built up above the surface level of the ground in which they are located. When such conditions are allowed to exist, surface waters arising from rain and melted snows flow into the cistern or well. On farms and country places the surface waters are contaminated with barnyard refuse largely composed of plant and animal wastes. In villages and small towns such waters are polluted with street washings, backyard refuse, and filth of every sort.

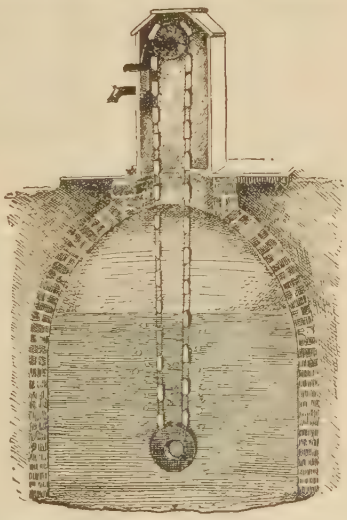


FIG. 123.—Chain pump. The inverted metal cups carry air down into the water which is liberated as the cups fill with water. (*Brownell's General Science.*)

A second source of contamination is found in the ground waters that percolate into the well. This is particularly true when the wells are badly located—too near to stables, barnyards, cesspools, and the like. All water before entering a well should percolate through 100 feet of soil in order to free itself of contaminating factors. If the soil is very porous, or if the water table drains toward the well, as shown in Fig. 125, it is quite clear that there are

serious chances of pollution. In short, the drainage of surface and ground waters should be away from the well.

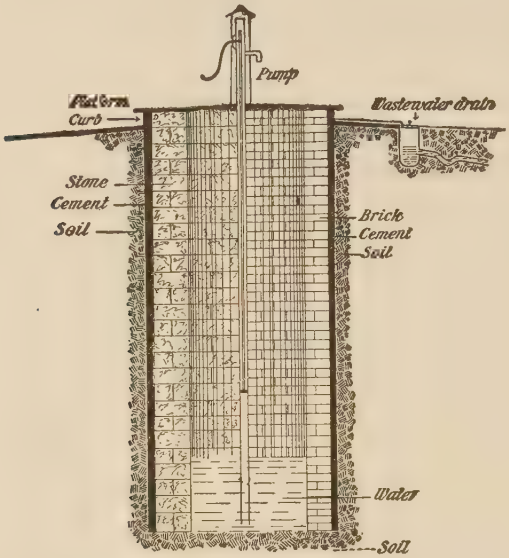


FIG. 124.—Construction of a model well. On the right is brick construction, on the left stone construction, as illustrated. (*From Marshall's Microbiology.*)

FIG. 125.—Contamination of well water. Drainage from the barnyard and cesspool forms a part of the well's supply of water. (*U. S. Public Health Service.*)

Surface wells and wells used only during the summer camping season should be often examined by a bacteriologist to determine

the state of purity of such waters. The fact that water is crystal clear does not prove its purity and the absence of dangerous bacteria that cause typhoid fever, dysentery, and other intestinal disorders. The best way to get rid of bacteria is to boil the water, a duty which people ought to remember when obliged to use doubtful supplies of water.

City Water Systems; the Great Lakes; Chicago.—The Great Lakes are the largest natural fresh water storages in the world. In this vast region a considerable fall of rain and snow keeps these huge reservoirs constantly supplied. On account of these never failing reservoirs of fresh water, we find great industrial centers located within reach of these natural storage basins. In this connection the experience and development of the Chicago waterworks system is typical of every great city situated in the neighborhood of the Great Lakes.

When Chicago was a village, the people obtained their water from wells. The wells were not deep and often allowed the surface waters to seep or drain into them, and as a consequence cholera and typhoid fever were nearly always present. In these days the people were careless and did not know a great deal about the "germ theory" of disease. Consequently the waste materials from typhoid patients found their way into many wells and food materials, all of which resulted in widespread epidemics of typhoid fever, and other ills.

At this time some of the people made use of the water from the Chicago River. At first it was quite safe and reasonably pure. Eventually, as the village grew and factories became more numerous, the water of the Chicago River became more and more polluted from the refuse of homes, factories, and streets. The epidemics of typhoid and other disease became not only more widespread but more intense. Water merchants and water peddlers became more and more in demand. These water venders dipped the water from Lake Michigan and hauled their supplies to those who could afford to pay for such service. The water peddlers were careless and often unclean, and as a consequence those families who bought water suffered the same as those who obtained their supplies from wells.

Masses of people are usually very slow in undertaking any measure for their common good. When outside enemies appear for the purpose of attack, the people are aroused to action; they lay aside their discord and organize themselves for carrying through defensive measures. While masses of people hasten to unite against an external enemy, they are slow to organize and design means for ridding themselves of internal dangers arising from disease and similar forms of distress and disorder. However, when disease epidemics become more and more frequent and widespread, the mass of inhabitants find themselves facing a common danger.

When the people of Chicago became weary of disease and alarmed at the number of deaths that were taking place, they saw that something must be done, and so they united in erecting a public water system. A reservoir was constructed, and a pipe line was extended about 150 feet into the lake. A small steam engine was installed to pump the water from the lake into the reservoir. Wooden pipe lines connected with the reservoir distributed the water to the several homes and shops. For a short time the people were happy, and the town grew and became prosperous.

As the town grew the reservoir became inadequate, and greater amounts of refuse and bacterial filth polluted the waters along the lake shore. The contaminated water again caused epidemics of typhoid and kindred diseases. A thorough study was made of the lake waters, and clean water was found to exist the year round at a distance of two miles from the shore. The problem of getting water located at such a great distance from the shore was a very difficult one for the engineers of that time. Finally, one of the city engineers conceived the idea of digging a tunnel under the lake to a *crib* or *intake tower* to be built at a required distance from the shore. Consequently a tunnel five feet high and five feet wide and seventy feet below the level of the lake was begun and completed in three years. When the tunnel was completed, it was joined to a large well over which a *water-works* building containing powerful engines and pumps was built. The pumps conveyed the water to a new and enlarged reservoir, from which large iron pipes carried the

water to the main sections of the city. Smaller iron pipes led out from the large main pipes to the dwellings and shops. Again the people were happy, and good water advertised the city far and wide as a good place in which to live.

New York and the Head Waters of the Catskill Mountains.—While Chicago, Cleveland, Buffalo, and other great centers located on the shores of the Great Lakes find inexhaustible supplies of fresh water so near at hand, many other great cities and lesser communities are not so fortunately situated. Some twenty years before the Civil War, New York City purchased the lands about the Croton River. Constructing an immense dam across the river, they created the great Croton reservoir. The reservoir was located about forty miles away from the city, and so it was necessary to construct the Croton Aqueduct to convey the waters of the Croton reservoir to the city. These huge projects—Croton reservoir and aqueduct—cost the people of New York City $160,000,000 and delivered 500,000,000 gallons of water daily. This immense quantity of water could not supply the increasing demands of the growing city. In order to increase its supplies of water the city purchased an area of 900 square miles of mountainous land located in the region of the Catskill Mountains. Great reservoirs store the rainfall of this region, and an aqueduct 130 miles in length conducts the vast storage supplies to the greatest water-using city in the world. The mountain storage and aqueduct are of sufficient size to meet the growing demands of the city for many years to come.

Los Angeles and the Lakes of the Sierra Nevada Mountains.—High up in the Sierra Nevada Mountains the City of Los Angeles has been able to enlarge the storage capacity of a naturally occurring reservoir by means of dams. These storage basins are fed by mountain streams that are free from organic wastes and many other sources of contamination, which often pollute the lowland streams. A great aqueduct 246 miles in length crossing mountains and canyons conducts the water down to the city. This aqueduct is able to supply 300,000,000 gallons daily, which is sufficient to meet the demands of a future population of 2,000,000 people. As the

water rushes through the aqueduct on its way to the city below, it is conducted through water turbines that turn electrical

FIG. 126.—A striking illustration of how mountains and forest clad highlands serve as reservoirs for the solid forms of water. The melting snow provides great volumes of water, that supply mountain lakes and springs, that serve as the head waters of rivers. (*Rio Grande Southern R. R.*)

FIG. 127.—Nature's method of storing water. By building a dam at the outlet of such mountain lakes tremendous reservoirs have been created for the storage of water. (*Rio Grande Southern R. R.*)

machinery. Thus the water renders a double service to the people of this community.

Cincinnati and the Ohio River.—The only source of water supply in the near neighborhood of Cincinnati is the muddy waters of the Ohio River. The raw water of the Ohio River is pumped into large *settling basins*, where the water deposits from 50% to 65% of its suspended materials. The surface water of the settling basins is conveyed to what is called a *head house*, where it is treated with a solution of iron sulphate, varying from 0.2 to 2.5 grains per gallon. Shortly after this the water receives a solution of lime—about 0.75 grains per gallon. When the water has received its supply of the two chemicals, it is conducted to the *coagulating basins*, where the finely divided clay and bacterial organisms are coagulated—brought together in masses—and precipitated to the bottom of the basin or reservoir.

The surface waters of the coagulating basins are conducted to a set of sand filters. The filters are built of concrete with V-shaped troughs, at the bottom of which are brass strainer plates. The troughs are filled and covered with fifteen inches of gravel, over which is a layer of fine filter sand having a depth of twenty inches. The water passes through the sand filters at the rate of about 112 million gallons per acre per day. When the water leaves the filter, it passes to a clear water basin, whence it is pumped to all parts of the city.

An average analysis for a year at the Cincinnati Water Works shows:

	Bacteria per cubic centimeter
In river water	24,930.0
In filtered water	16.0
Percentage of removal	99.94

Furthermore, following the installation of the filtration plant typhoid fever began to decline. During the seven years preceding filtration, 1351 deaths were caused by typhoid. During the seven years following filtration, 249 deaths were due to this

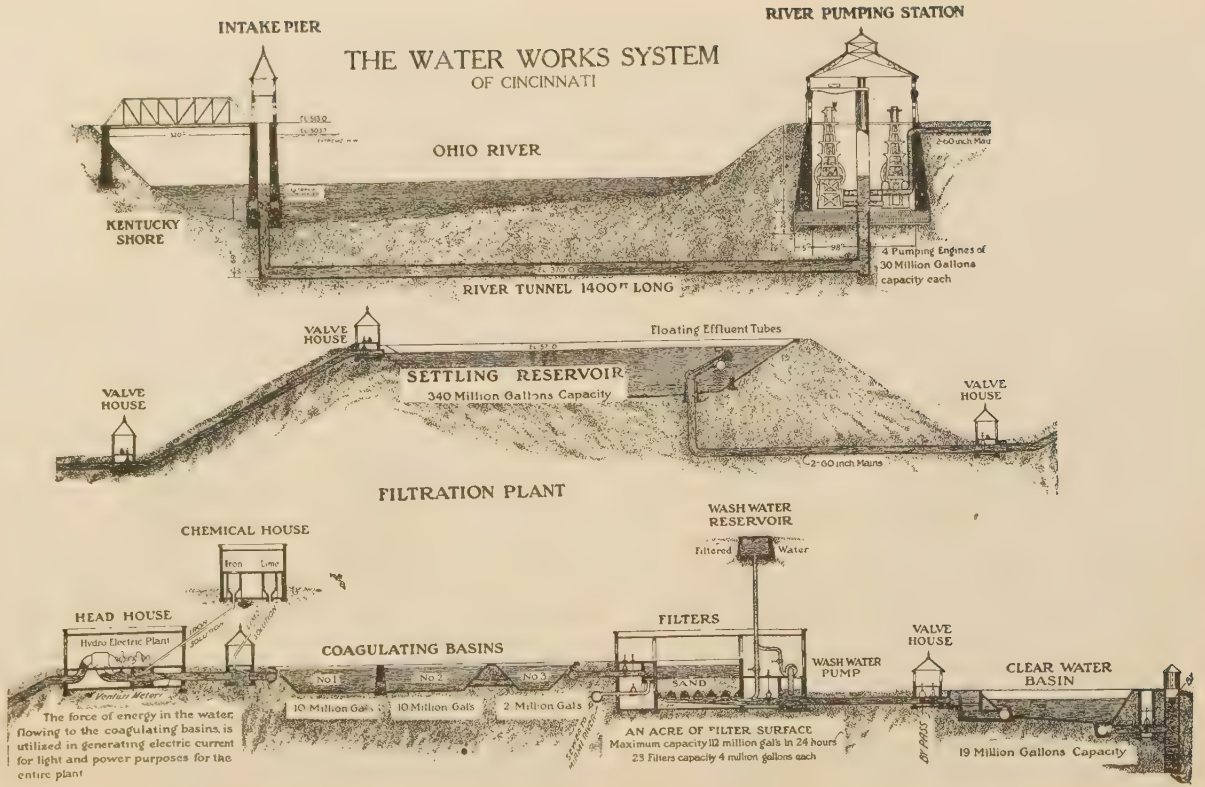

THE WATER WORKS SYSTEM
OF CINCINNATI
INTAKE PIER
RIVER PUMPING STATION
OHIO RIVER
KENTUCKY SHORE
4 Pumping Engines of 30 Million Gallons capacity each
RIVER TUNNEL 1400ft LONG
VALVE HOUSE
Floating Effluent Tubes
SETTLING RESERVOIR
340 Million Gallons Capacity
VALVE HOUSE
VALVE HOUSE
2-60 inch Mains
FILTRATION PLANT
CHEMICAL HOUSE
Iron
Lime
WASH WATER RESERVOIR
Filtered Water
HEAD HOUSE
Hydro Electric Plant
Venturi Meter
COAGULATING BASINS
No 1
No 2
No 3
10 Million Gals
10 Million Gals
2 Million Gals
FILTERS
SAND
WASH WATER PUMP
VALVE HOUSE
CLEAR WATER BASIN
The force of energy in the water flowing to the coagulating basins, is utilized in generating electric current for light and power purposes for the entire plant
AN ACRE OF FILTER SURFACE
Maximum capacity 112 million gals in 24 hours
25 Filters capacity 4 million gallons each
19 Million Gallons Capacity

FIG. 128.

cause. With an increase of 50,000 in population, there has been a saving of 1102 lives from this disease alone.

This method of purifying river water is very efficient and is being used by towns and cities for the purification of waters from various sources. By a similar method the people of St. Louis purify the muddy waters of the Mississippi River.

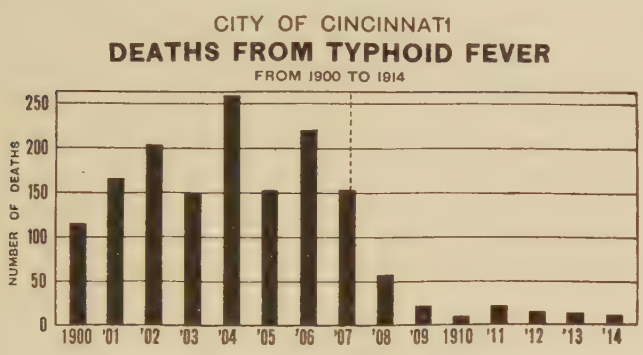


FIG. 129.—Note filtration plant in service October, 1907. Population of city increased 10.1 per cent from 1910 to 1920.

The Need of a Sewage System.—In a rapidly developing community where the population is increasing and the industries are multiplying, we find human wastes and factory refuse accumulating to such a degree as to threaten health and life. Indeed, in ancient times villages and cities were abandoned, or populations wiped out, because of the bacterial infections that arose from the accumulation of wastes. Streams and rivers must be used to carry away the contaminating wastes, or severe laws must be passed to limit industry and settlement. Hence in our present state of development, water has become the principal means for carrying away the burden of things we no longer want about us.

As a consequence every American city has two great systems spread throughout the community. One system is used to carry and distribute vast quantities of fresh and wholesome water to every home and factory in the community. The other system—sewage—collects all the wastes of the home and factories and transports its foul load to settling basins or directly to some body of water—a river, a lake, or an ocean.

When the receiving body is a river whose volume of water is large, the foul waters received from the sewage basins are well diluted and soon exposed to the sunlight and air in its course down stream. Hence, before the stream waters have traveled many miles, they have purified themselves.

Often times rivers receive such an overload of sewage that their waters are befouled and dangerous to the health of communities through which they pass. When such rivers empty into lakes, the lake waters are likely to become polluted for great distances from the shore. Not long after the people of Chicago had perfected their wonderful water system, they found that their water was again impure. They could not think why this could be so, for their intake tower or crib was located out in the pure waters of the lake. They soon found the reason to be that the Chicago River, which received all of the city sewage, was unable to dilute sufficiently and partly purify the vast quantities of sewage poured into it. Since the river flowed into Lake Michigan, the lake waters received sewage wastes which the storms and under currents often carried far out into the lake. When the citizens learned these facts, they decided to make the Chicago River flow the opposite way. So in 1889 they began to dig a drainage canal. The completed canal turned the waters of the Chicago River into the streams that flow into the Mississippi River. Since then Chicago's water has been pure, and the old time epidemics of typhoid fever and other diseases have not recurred.

Sewage Treatment.—One method of sewage treatment has been already suggested—the dilution of sewage waters with large volumes of fresh water. This method of treatment is the one employed in the Chicago district, where the heavy flow of sewage is diluted with water drawn from Lake Michigan and adjacent waterways before it is allowed to leave the drainage canal and to enter the Des Plaine River, a tributary to the upper courses of the Illinois River. While the people of Chicago have solved in a measure their local sewage problems, they do so at the discomfiture of others.

In 1915 a report on "The Disposal of Sewage and Protection of Water Supply of Chicago" was made by Soper, Watson, and

Martin. The report reads in part as follows: "For over 100 miles from Chicago, the inhabitants of the valley have relinquished the most valuable rights of land owners. The water is not fit to drink or wash in, nor to water stock in, nor for any domestic and industrial purposes of a normal river. Fish die in it; the thought of swimming in it is distasteful to the senses; boating far from a pleasant and healthful diversion is repugnant. The stream flows with majestic sweep of all great rivers and the banks are overhung with rich luxuriant foliage; but the water is discolored, malodorous, and poisonous." Thus it is evident that, while discharging diluted and unpurified sewage into the nearest stream is a very satisfactory method so far as the polluting community is concerned, the communities down stream must suffer and really pay for and bear the burdens that arise from such methods.

Cities situated on the seaboard are more favorably located for disposal by dilution. The volume of the diluting water is large, and no chance of contaminating water supplies exists. The salt water exerts a precipitating action upon sewage solids, which are thus quickly disposed of. In the case of New York 500,000,000 gallons of sewage are poured daily into the harbor. The harbor is large enough to take care of all that is discharged into it without the creation of a general nuisance within its waters.

Many methods for partly ridding sewage waters of their wastes have been employed, and others are coming into use as more study is being given to the problem. One of the earliest and simplest methods and one still in use is the employment of coarse strainers. Large bars are placed upright in the sewage stream, and, as the waters flow through, much debris is thus held back and removed by mechanical rakers. Another device is the *septic tank*. This tank is made up of two or more compartments. The incoming sewage is brought to rest in the first tank, where settling-out processes take place. As the layers of sludge collect on the bottom of the tanks, great numbers of bacteria set to work on the organic wastes and change them to liquids and gases. The top layers of the liquid drain over into a second compartment and sometimes into a third before

reaching an outlet drain. While passing through the septic tanks, the sewage waters have lost anywhere from 40 to 65% of their suspended solids.

In some localities a *contact filter bed* is used. These beds are made of crushed stone or gravel. As the sewage filters through the crushed stone or gravel, it is acted upon by bacteria that change the organic wastes to liquids and harmless gases. In each of these methods—*septic tanks* and *filtering beds*—we have instances of the usefulness of some forms of bacteria and lower forms of life.

Mosquitoes and Disease.—Scientists have definitely fixed upon the mosquito the responsibility for every case of malaria and for every case of yellow fever. Just as a farmer must plant seeds of corn or barley in the soil of his fields to obtain a crop of corn or barley, likewise must the mosquito first plant the germs of malaria or yellow fever in the tissues of our bodies before we can suffer from either of these diseases. It is now well known that there are many kinds of germs which do not float in the air to be broadcasted by every breeze that blows, but which must be carried from person to person. There are even germs, particularly those belonging to the lower animal forms—protozoa—that depend entirely upon some insect for their existence. If this particular insect should perish as a race, the disease germ would likewise perish and pass out of existence. Hence, if there were some means of ridding the earth of mosquitoes, there would be no malaria or yellow fever.

Everyone is familiar with the fact that there are many kinds and varieties of dogs—shepherds, hounds, terriers, and others, but few people know that there are many kinds and varieties of mosquitoes—*Culex*, *Anopheles*, *Stegomyia*, and many more. The commonest of all mosquitoes is the *Culex*, which breeds wherever water stands. The Anopheles or malaria mosquito breeds only in fresh water pools, while the Stegomyia or yellow fever mosquito develops its kind in any stagnant body of water, even in houses and cellars. The malarial and yellow fever germs are parasites and find their food in the blood of man or in the fluids in the body of the mosquito. In either case the germ can live only a part of its life in man; the other portion of

its life it can spend only in the body of a mosquito. Thus the malarial germ has two hosts—man and *Anopheles;* the yellow fever germ, man and *Stegomyia.*

Fig. 130.—The female mosquito. A malaria-bearing mosquito (anopheles maculipennis) showing the characteristic attitude when stinging. (*From the cast in the American Museum of Natural History, New York.*)

When a female mosquito, *Anopheles*, bites a person whose blood is at a certain stage of malarial fever, it will take in and hold in its stomach forms of malarial spores. These spores will thrive and develop active forms of the malarial germs,

because they find food in the *Anopheles* on which they can develop. The *Anopheles* is the only variety of mosquito that can furnish the proper food for the development of the active form of the malarial germ. After a period of a week or so, this *Anopheles*, if it bites a healthy person, will plant in the blood malarial parasites of the active form. This parasite will multiply in the person's blood and form many more millions of spores. During the formation of these vast hordes of malarial parasites within the blood, the person suffers chilling effects. This is due to the fact that the malarial protozoan is robbing foods out of the blood that belong to the tissues of the

FIG. 131.—Resting posture of mosquitoes. (1) and (2) Anopheles. (3) Culex pipiens. By means of their resting postures the harmless culex may be distinguished from the Anopheles which spreads Malaria. (*From P. H. Reports. After Sambon.*)

body. It is now regarded as a fact that no one can have malarial fever unless bitten by an *Anopheles*, and likewise that no one can have yellow fever unless bitten by the *Stegomyia*.

The Mosquito and Its Relation to Water.—Since the mosquito spends the first portion of its life in standing water, the eggs are deposited on the surface of quiet waters. The common mosquito deposits at night from 250 to 400 eggs. The egg masses are held firmly together and float like a raft. In from fifteen to twenty hours the eggs are hatched, producing larvæ, which are commonly called "wrigglers" on account of the jerky motion which they have when moving about in the water. When fully grown they are about one quarter of an inch in length and come to the surface every minute or two to breathe. In from eight to nine days the larvæ pass into a second stage called the pupa stage, in which the head is greatly increased in size, with two tube-like structures that look like horns. The horn-like structures are breathing tubes which

are often thrust above the surface of the water for the purpose of getting air. In two or three more days the shell of the pupa cracks, and out climbs a young mosquito, who after drying his wings flies away to take up the life of the adult form.

Since the mosquito larvæ can develop only in water, it is quite evident that there can be no relief from mosquitoes without the destruction of their breeding places. As a matter of

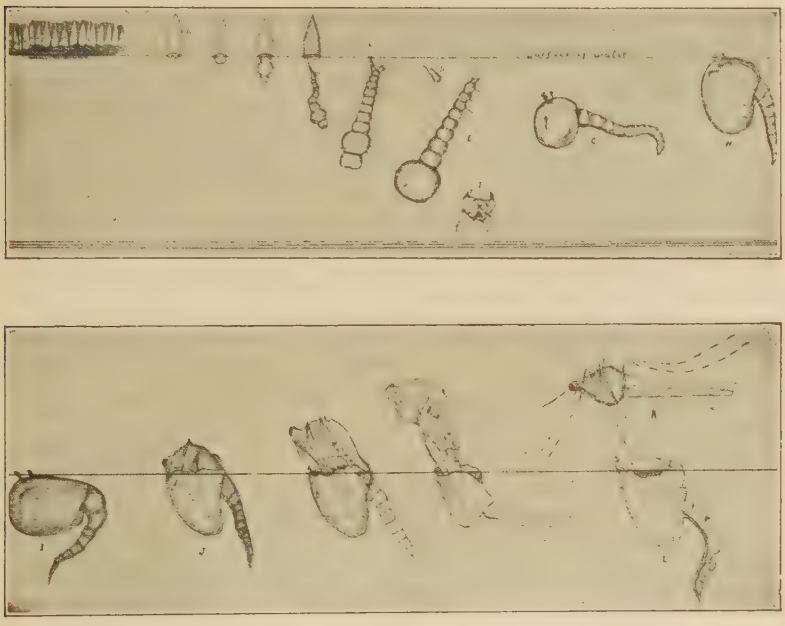


FIG. 132.—The mosquito's life history. *A*, A cluster of eggs, called "an egg-boat;" *B*, a single egg standing on the surface of the water and showing in the series the hatching of the larva, or "wriggler;" *C*, a young larva with its breathing tubes in contact with the air; *D*, the terminal tube, dropped off when the "wriggler" changes to a pupa; *E*, the first form of the pupa; *F*, the larval head discarded; *G*, a pupa nearly formed, showing the funnel-shaped tubes at the "forehead," through which it must now breathe; *H*, a young pupa breathing; the outlines of the mosquito begin to appear; *I*, a fully developed pupa; *J*, a mosquito beginning to hatch; he does not touch the water; *K*, fully hatched and standing on the water to dry; *L*, the pupa shell left floating on the water.

fact these breeding places may be found wherever water can accumulate and stand for a few days. It is comparatively easy to drain a marshy spot in the lawn or garden. Large numbers have been found to breed from rain that collects in

hoofprints by the roadside, chicken pans, horse troughs, discarded cans in the back yard; indeed any receptacle in which rain water finds lodgment will serve as a breeding place for mosquitoes.

In order to rid a community of mosquitoes, the best way is to drain all standing water or to fill the depression. This is a permanent method and gives the best results. Another is to keep all waters for domestic use well screened, and provide for a layer of crude petroleum on cess-pools and other standing bodies of water not so easily drained. The layer of oil on the surface of the water prevents the mosquito from obtaining a proper supply of oxygen from the air, and thus it dies from suffocation. A third method is to stock all ponds and marsh waters with fish, which feed upon the young larvæ of the mosquito. However, the shallows and the dense plant growth that takes place in some swamps exclude the fish from many areas of the body of water, and consequently the mosquito breeds without much interruption.

Projects

1. To make a study of the source of all water supplies that are used in the community.

2. To make a study of those conditions that lead to the contamination of waters used for household purposes.

3. To make a study of the local water system and its method of purification.

4. To make a study of the local method of sewage disposal and to determine whether or not the method used brings hardship and loss of privileges to those living in the districts in which the sewage wastes are disposed.

5. To make a study of the various methods of sewage disposal in order to point out the advantages and disadvantages of each method.

Limit your study to three of the major methods now employed:

(*a*) Direct to streams, rivers, lakes, bays, and harbors.

(*b*) To streams, rivers, etc., after dilution with water.

(*c*) To streams, rivers, etc., after purification in septic tanks or filter beds.

6. To make a report on the work done by Col. W. C. Gorgas in ridding Havana, Cuba, of yellow fever.

7. To make a report on the work done toward the extermination of the mosquito in the Canal Zone.

8. To make a survey of the community about the home in order to report the location of conditions favorable to the breeding of mosquitoes.

9. To organize the people of the home district into a clean-up campaign for the removal of all conditions favorable to the breeding of mosquitoes, flies, and other pests.

10. To write an article for the local press.

Suggestions:

(*a*) "Better water."

(*b*) "Better methods of sewage disposal."

(*c*) "The necessity of a clean-up campaign."

(*d*) "An effective campaign against mosquitoes."

(*e*) "Conservation of water supplies."

(*f*) "Good water and its relation to good health."

(*g*) "Good water is the best advertisement of a progressive community."

(*h*) Other topics more suitable to the community in which the pupil lives may suggest themselves.

11. To make a study of the Roman Aqueducts and their relation to the life of those historic times.

Suggestions.

(*a*) Why were the aqueducts built?

(*b*) Where were the aqueducts built?

(*c*) Of what materials were they built?

(*d*) What volume of water did they deliver?

(*e*) Are some still in operation?

(*f*) Did the Spanish people build aqueducts?

(*g*) Did the Spanish build aqueducts in America? Where? When?

(*h*) What is the general conclusion from such a study of aqueducts?

CHAPTER XV

HOUSEHOLD AND INDUSTRIAL USES OF WATER

Object.—To make a study of the various uses to which water is put in present-day methods of living.

Uses of Water.—The preceding chapter states that man's first need of water is *for the support of life*—for drinking purposes. Continued health is dependent upon water—wholesome water. Absolute purity in water cannot be had, but water must be had that is free from disease germs and poisonous wastes of whatever kind. The next greatest use of water is *for the production of foods*. After air and water man needs a constant supply of food for bodily growth and repair and the maintenance of strength. The source of man's food is found in the tissues of animals and plants, all of which require water. Soils of whatever kind are of no use without sufficient water supplies to insure the growth of plants which serve as foods for man and animal. Consequently water storages for the irrigation of crops and for the raising of livestock have come into use.

The third use of water has already been discussed—*a transport for the disposal of wastes* in sewage systems. The use of water in sewage systems for carrying away the wastes of the home and factory has been a happy solution of an ancient difficulty that brought death and disaster to many communities of past history. True, some abuses have arisen from the pollution of streams and rivers, but progress is being made; and as the people become more educated, they correct the evils that now arise from indifference or a lack of information.

The fourth use of water is its application in the industries for the preparation of foods and the production of power. Large volumes of water are used in almost every sort and kind of industry—in meat packing and ice making, in steam boilers and turbines, and in other ways. The fifth use of water is for transportation. From the earliest history man has used the

waterways of the earth as transportation routes. The water bore up his heavily laden boats which could be easily moved before the oar and sail. Similar loads by pack and caravan caused a good deal of trouble, delay, and heavy toil, as compared with those moved along the waterways.

The demands for water today as compared with those in colonial days are enormous. In those early times the average demands per person were less than two gallons per day. Today the community finds the average personal demands are 150 gallons per day, with a tendency toward a still greater demand. These increased demands are due to raised standards of living—higher ideals of personal hygiene, household sanitation, and community cleanliness. The possibility of supplying these ever increasing demands is due to the invention of machinery to which has been harnessed nature's forces as found in the waterfalls and fields of coal. The great civilizing influence due to the possibility of satisfying the demands for more water will be better understood after our attention has been directed to some of the more important uses to which it is put.

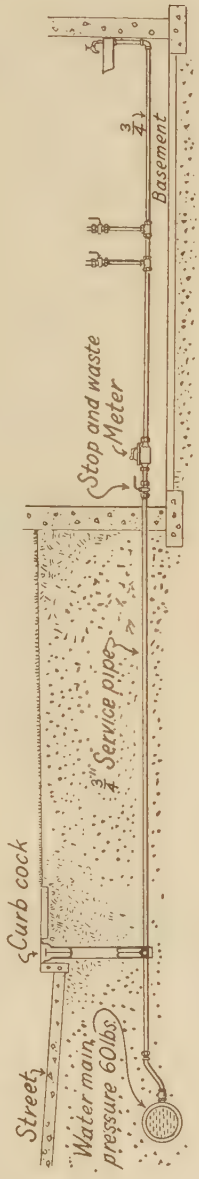


FIG. 133.—Water main connected with residence main. Observe curb cock, stop and waste cock, water meter, and the location of each.

HOUSEHOLD PLUMBING (HOME WORK)

Object.—To make a study of the means and methods employed in a modern home for receiving and distributing supplies of water. To make a study of the sanitary conveniences that are provided for the disposal of waste waters and waste materials.

PROCEDURE.—(*a*) The cold and hot water system.—1. Locate the pipe line that conducts the water from the city mains to the pipes in the home.

Does the water pass through a water meter before it enters the pipes of the home? Observe the dial of the water meter while the water flows from an open faucet. Read the meter.

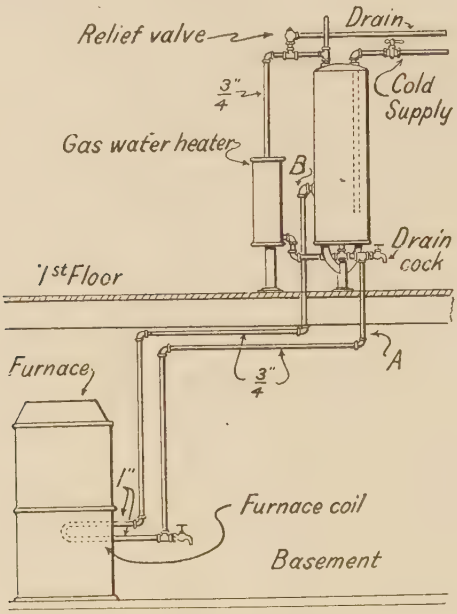


FIG. 134.—A hot water tank may be heated from two sources, the furnace or the gas heater.

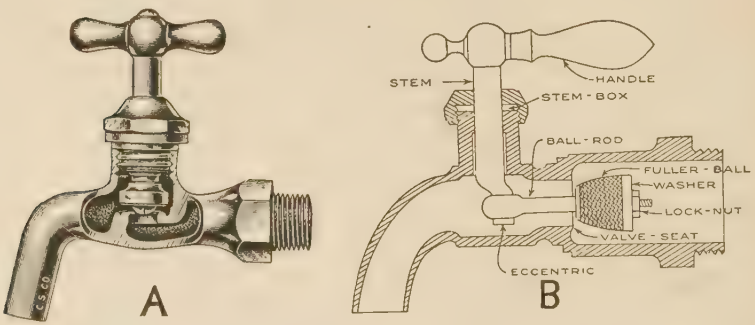


FIG. 135.—Faucets. *A*, screw type; *B*, compression type.

2. Is there a provision for shutting off the water supply in the basement of the home? In the yard? When is it necessary to use these means of shutting off the water supplies?

3. Trace the cold water pipe to different parts of the building or to the various rooms which it supplies.

4. Where does the cold water pipe enter the hot water tank? Where does the hot water leave the tank? How is the water heated and circulated in the hot water tank?

5. Locate and count the number of cold water faucets; the hot water faucets. Are all the faucets in good working order? If not, are you able to make the necessary repairs? There are three types of water faucets: the compression type, Fig. 135 (*B*); the screw type Fig. 135 (*A*); and the spring type. In the compression type the Fuller-ball needs renewal when the water drips after the faucet is closed. In the compression type a rubber disk requires occasional renewal. Any boy or girl ought to learn how to turn off the water supply and make the renewals in such faucets whenever

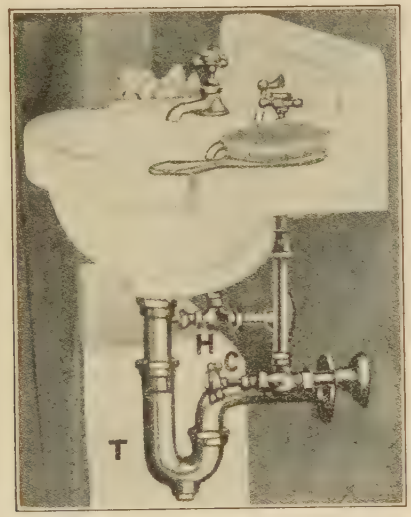


FIG. 136.—Wash bowl and plumbing. *C*, cold water pipe; *H*, hot water pipe; *T*, drainage pipe showing water trap.

necessary. The Fuller-ball or rubber disk of proper size may be obtained at a small cost from dealers in hardware.

(*b*) The sanitary system.—1. Make a study of the drain pipe leading from the kitchen sink or the wash bowl in the bath room. Make a sketch of the curves and bends that you observe in the drain pipe.

What portion of the bend serves as a "water trap?" Is there a removable plug at the bottom of the bend in the water trap? Remove the plug, being sure to have a receptacle underneath the plug while removing it. Of what use is the removable plug and why is it placed as it is? What is the reason for keeping water in the trap?

2. Trace the drain pipe to the point where it leaves the house. What becomes of the waste waters that flow through the drain pipe? Compare the size of the drainage or sewer pipes with the water pipes. Why the difference in size? In which system is the water under pressure?

HARD AND SOFT WATER

Object.—To make a study of the conditions that give rise to soft and hard waters. To discover means whereby hard water may be softened.

Materials.—Bottle of lime water. Solution of calcium chloride and calcium sulphate. Solution of soap in alcohol or water. Distilled water. Rain water or water from melted snow. Three or four large test tubes or bottles. Glass tubing, 6 inches.

Procedure and Observations.—1. Fill each of the test tubes ⅓ full with distilled water. Number the tubes #1, #2, #3. To the water in tube #2 add a few drops of calcium chloride. Add calcium sulphate to #3.

2. Add two drops of soap solution to each of the three tubes and observe closely to see what takes place as the drops spread through the liquids. In which cases do you observe a white and curdy percipitate?

3. Placing your thumb over the tube shake the liquids. In which of the three cases do bubbles or *lather* appear upon the surface of the liquid? Add two drops more of soap solution and repeat the shaking. Observe again the tube or tubes in which lather has formed.

The tubes containing the solutions of calcium chloride and calcium sulphate behave like "hard" waters because of the presence of calcium salts. Whenever calcium compounds become dissolved in water, the waters are defined as "hard" waters. The calcium salts and soap combine and form sticky precipitates which ruin clothing materials washed in their presence.

4. Place some lime water in a test tube and, by means of a glass tube, "bubble" your breath through the lime water. What happens? Continue to bubble your breath through the water until the water in the tube becomes again clear. You now have acid calcium carbonate in solution and the water is known as water of *temporary* hardness. Pour ½ of this water into a second tube.

Add two drops of soap solution to one of the tubes. Is there a milky percipitate? Is the water "hard?"

Warm the remaining half of the water and observe closely what happens. Does the water again become milky and then finally clear when a white insoluble powder settles to the bottom of the tube? The water which was temporary hard is now soft water, because the calcium salts which were in solution have settled out. Add one drop of soap solution and shake. Does a lather form? If it does it shows the water to be soft. Water that is *temporary hard* is softened when heated and the teakettle becomes coated with a layer of calcium carbonate.

5. Only waters containing acid calcium carbonate are *temporary hard*, and only these waters may be softened by boiling. Waters containing calcium or magnesium sulphate have *permanent hardness*.

6. Is rain water hard? Test it. Is water from melted snow hard? Test it. Is the tap water hard? Test it.

7. Make some hard water by adding some calcium sulphate solution to some distilled water. Add a few drops of washing soda. Does a white precipitate settle out? Decant the top waters. Are the decanted waters soft or hard? This is one method of softening waters. Repeat with borax in the place of washing soda. Are hard waters expensive to the householder? Give reasons.

USES OF WATER. (HOME PREPARATION)

Object.—To make a survey of the home and community in order to learn the everyday uses of water.

PROCEDURE.—(*a*) In the home.

Make a list of all the uses to which water is put in and about the home.

(*b*) In the factories and industries.

Make a list of the factories and industries located in the community that make use of water in their manufacturing processes. Arrange the industries according to quantities used. For example, ice plants use water almost exclusively. Then, secondly, meat packing plants use large volumes of water for washing meat products and cleaning buildings, etc.

(*c*) Municipal uses.

Example: Washing and sprinkling streets, fire protection, etc.

(*d*) Harbors.

Freight boats, canals, etc.

(*e*) In the communities about the city.

Power purposes—water wheels, etc. Watering livestock, etc.

Water the Universal Solvent.—When a spoon full of sugar is put into a glass of water, the sugar gradually disappears from sight. The resulting liquid is clear and transparent, and by merely looking at the liquid we can not tell a glass that contains sugar in solution from one that simply contains pure water. However, when we taste the liquid in either glass, we are quickly informed as to which of the two contains the solution of sugar. We also know that stirring hastens the action of solution, and for this reason we stir our coffee and tea. Furthermore we know that the sugar goes more rapidly into solution in hot tea than in ice cold tea. Knowing this, the housewife speeds up the dissolving action of water by warming or heating the vessel in which she is attempting to dissolve substances. Just how substances go into solution is beyond our power to see. But when a drop of the liquid is placed on a piece of glass and allowed to evaporate, the sugar, or salt, or other dissolved

substance is left behind in a solid state. This is one of the best tests that can be applied to any body of water in order to determine whether or not it contains solid substances in solution.

Not every solid substance is soluble in water. We know that the cup, or the glass, or the jug, or similar container does not go into solution in the water that it contains. The sand by the seashore is ever present and resists well the dissolving action of water that flows over it or piles it up along the coast. Yet so many materials are soluble in water that it has become known as the "universal solvent." A substance like water, which has the power of dissolving another substance, is known as a *solvent*. The substance that goes into solution is called the *solute*.

Furthermore it is well known that fats, oils, and greases do not dissolve in water. Consequently when we wish to remove oil or grease from clothing materials, we must use a suitable solvent, such as alcohol, benzine, chloroform, or ether. In the preparation and manufacture of medicines, paints, and varnishes, water is quite unsuitable as a solvent. Such substances as oils, grease, paints, sulphur, charcoal, iron, gold, marble, and the like that do not dissolve in water are said to be *insoluble in water*. Sugar, table salt, soap, washing soda, and the like that dissolve in water are said to be *soluble in water*.

The solvent action of water is not limited to certain solids like sugar and salt. Many gases like ammonia and carbon dioxide are very soluble in water. Gases like oxygen are fairly soluble in water, and it is the dissolved oxygen in cool waters that sustains the life of fish and like water animals. When the supply of dissolved oxygen is used up or missing from bodies of water, fish and similar water animals suffocate and die. Liquids like alcohol and glycerine are very soluble in water; indeed these two substances are soluble in any proportion in a body of water. Hence the use of water in the many arts of life is dependent upon our knowledge of its suitability as a solvent for whatever purpose we desire to employ it.

Hard and Soft Waters.—As the ground waters percolate through the sand and rock layers of the earth, they dissolve out any soluble salts with which they may come into contact.

Hence when such waters are brought to the surface for domestic and industrial uses, we find that they contain the soluble salts of calcium and magnesium. Such waters are known as *hard waters*.

Hard waters are classified into two kinds, those of *temporary* hardness and those of *permanent* hardness. Those of temporary hardness contain varying amounts of acid calcium carbonate in solution. The acid calcium carbonate is removed by simply heating the solution. The heat breaks up the acid calcium carbonate and leaves an insoluble substance known as calcium carbonate, which forms in layers on the inner walls of the teakettle or steam boiler in which water of temporary hardness is heated. Thus water of temporary hardness is softened by simply heating it.

Waters of permanent hardness are waters that contain various amounts of dissolved calcium sulphate or magnesium sulphate. These waters cannot be rid of their dissolved salts simply by being heated. Hard waters are quite useless as cleansing and washing agents unless they have been properly softened. When soap is added to hard water, an insoluble sticky substance is formed by the action of the soap with the calcium or magnesium salts that are in solution. If hard waters are used for washing the hands and face and for bathing, this curdy precipitate from the soaps and dissolved salts causes unsightly scums on the side of the wash-bowl and bath-tub. These sticky particles, or precipitates as they are called, tend to fill the pores of the skin, to prevent thorough cleansing, and to cause the skin to chap. It is in the laundry that the effects of hard waters are the most noticeable. When clothing materials and soap are placed in hard water, the sticky precipitate forms in and between the fibers of the clothing and thus ruins them. Hard waters also encourage the use of strong soaps and washing compounds of all sorts and varieties, all of which often contain ingredients destructive to the fabrics and their color.

In order to render hard waters soft the housewife must add enough soap, or washing soda, or borax to settle out the calcium and magnesium salts that make the waters hard by their presence. Such hard waters must be run into barrels or tubs and

treated with soap or borax or other softening agents and allowed to stand until the curdy precipitates have all settled. When the curdy materials have settled to the bottom of the barrel or tub, the top water, which is now soft, is dipped out and used for washing purposes. This method of softening water involves a loss in labor, time, and money.

In the industries waters of permanent hardness are the cause of heavy deposits of calcium and magnesium salts on the inner walls of boilers and pipes. Waters of temporary hardness cause the same trouble, if not previously softened by heating or other processes. Water that contains the salts of iron in solution are very annoying to the householder. By the precipitation of iron oxide, the water becomes turbid, makes stains of iron rust on clothes, chokes up the pipes and tanks, and forms brown stains in marble washbowls under faucets.

In cities and villages in which water is supplied by public water systems, the question of hard waters is a community problem. The expense and labor of softening the water in the several homes and in the factories might be done at the water works plant with less cost to the community in the way of taxes than in bills for soap, softening agents, labor, and various other costs arising from the inconvenience of hard water.

Some cities have already installed softening plants in order that a high grade of soft water may be distributed to its inhabitants. Some cities have been especially favored by having a source of pure cold water near at hand. At Portland, Oregon, the melting snows of Mount Hood collect in a natural mountain reservoir at an elevation high above the city. The waters from the melted snows are entirely soft and pure and cold. The reservoir is well protected, and a pipe line conducts the water from this elevated point to the water mains of the city. As the pipe line descends, the water pressure within the pipe becomes greater and greater, until finally, when the city is reached, the water is under considerable pressure which is ample for fire protection and distribution throughout miles of water mains. This water is as near purity as nature can supply it. An analysis shows that these waters contain less

than 1.4 grains of dissolved mineral salts per gallon with little or no organic matter. The waters derived from mountain snows are ideal for all purposes, and one of the cheapest supplies that the city can have. The absence of salts that cause hardness in water makes the soap consumption of this city one of the lowest in the United States.

FIG. 137.—At Portland, Oregon the melting snows of Mount Hood collect in Bull Run Lake (in the right foreground) situated in the Cascade National Forest at an elevation of 3500 feet. The water is as near purity as nature can supply it. (*Courtesy of the Portland Chamber of Commerce.*)

Water and Individual Needs.—As previously stated the first use of water to a living organism is for sustaining life and health. Consequently the first need of water to man is a supply of water to quench his thirst and to satisfy those bodily requirements necessary to the maintenance of health. The amount of water actually needed for the support of life is relatively small. Under normal conditions the average individual requires daily about four pounds—two quarts—of water. But the individual's other needs connected with cooking, washing, bathing, and cleaning require all the way from 100 to 200 times the quantity needed for drinking purposes. Added to this is the

city's use of water for the disposal of sewage, washing the streets, extinguishing fires, sprinkling parks, operating fountains, etc., all of which must be averaged up and charged to the individual needs. For the individual is a member of the community and shares in its comforts, conveniences, and advantages as well as its discomforts, inconveniences, and disadvantages. In European cities 50 gallons per day per person are the usual requirements, while in American cities the total average requirement per person averages from 100 gallons per day in some cities to

FIG. 138.—A street washer. In progressive cities street washing machines are busy night and day washing the streets free from every sort of debris. This method of cleaning does not befoul the air with dust and disease germs. (*Courtesy of the Street Cleaning Dept., Cincinnati, Ohio.*)

160 gallons in others. As civilization advances, our demands are more exacting, and all our requirements reach a higher and higher plane as the possibilities for satisfying such requirements are made easier.

Water and Its Relation to Food Production.—As our population becomes more and more numerous, the question of food supply becomes also more and more pressing. Furthermore our city populations are drawing greater numbers from the farms and

farm occupations each year. The result is, of course, that those remaining on the farms must produce greater supplies in order that those working and living in the cities may have materials to serve as food, clothing, and raw materials for manufacturing purposes. This is only possible by greater use of much improved machinery, which enables the farmer to prepare larger fields for the planting and harvesting of larger crops.

Machinery, however, is of little importance if the soil is poor, or if there is a shortage of rainfall and other water supplies. In

FIG. 139.—Irrigation of trees. (*From Brownell's General Science.*)

the semi-arid and arid regions of the west, there are wonderful areas of soil rich in plant foods. But these areas are quite useless, owing to insufficient water supplies. In order to turn these regions into fertile fields, the national and state governments have established irrigation projects in many places. Systems of irrigation are brought about by the creation of reservoirs in high mountain valleys or table-lands, where natural barriers make possible the storage of vast quantities of water that drains from higher sources in the mountains. Conduits, canals, and irrigation ditches conduct the water to the fields to be irrigated. Already great areas of arid lands have been reclaimed for the raising of grain, livestock, fruits, and vegetables of every sort.

The crop yields are heavy and independent of drought and flood conditions that destroy annually large areas of growing and ripening crops in those regions dependent upon the usual rainfall. The fruits, nuts, grains, and other forms of produce that are raised in the irrigated regions of the west find their way through the markets to every table of the nation. Without these annual food resources, the comfort and security that we find in our present way of living would be limited and we would be hard pressed.

The present outlook is that there is not sufficient water in western highlands for the irrigation of all the arid regions that might serve in the production of food and clothing materials. Some water supplies that are still available remain to be brought into use. Other water supplies appear to be out of reach or require too great an expenditure to bring them into use. Thus the future development in arid regions must rest largely upon the enterprise and the engineering skill of men and women who are the boys and girls in school today.

In the lower Mississippi Valley and to a certain extent in many other regions of the United States there are vast tracts of fertile land which have an excess of water, and before grains can be successfully raised the land must be drained. Here the engineer is required to solve problems of drainage. In a great many ways the problems of drainage are quite similar to those of irrigation, for the drainage engineer must see to it that sufficient moisture is left in the soils for the proper development of the crops. When properly regulated, drainage systems insure crop yields as abundant as those of irrigated regions.

In connection with food production it should not be forgotten that water is essential for raising livestock and for the maintenance of animal industry of whatever kind. In all sections of the country springs, streams, rivers, and wells make possible the success of cattle, hog, and sheep raising that supply the American home with an abundance of meat-foods that is quite unknown in many countries. The following table gives an idea of the quantity of meat-food produced in the United States for a year just before the World War when conditions were in every way quite normal.

Kind	Quantity, pounds
Beef, live weight	8,300,000,000
Veal, live weight	400,000,000
Mutton and lamb, live weight	1,000,000,000
Pork, live weight	7,900,000,000
Value (for 1910)	$1,400,000,000

Figures given in the nearest number of 100-million pounds.

Water and the Preparation of Food.—In the home, quantities of water are daily used in the preparation and cooking of foods. Every kind of vegetable and fruit is washed free from all adhering materials preparatory to cooking or serving. Meats are cooked by means of boiling water, or dishes are prepared with meats in which water has taken part. Baking and canning processes take their share of water not only in the actual processes but for cleaning and sterilizing the several utensils used in the process. While the amount of water used in any one home for the preparation of foods is not great, the total for any community is large. It is the use of water in the home that prompts the community to supply adequate quantities that are wholesome and free from bacteria, odors, mud, and poisons of any kind.

In colonial days the preparation and cooking of foods were done wholly in the home. Today it is entirely different. The meats of all kinds are prepared from animals slaughtered in great meat packing industries that are not far from the grazing and feeding lands in which the animals are raised. In these vast and complicated industries water is the great essential in cleaning the meats and cleansing the floors, walls, tables, troughs, basins, and implements used in the packing processes. Other industries that require great amounts of water for the preparation of foods are bakeries, dairies, canneries for vegetables and fruits, and refineries for sugar from sugar cane, sugar beets, and corn starch. Many lesser industries engaged in the preparation of food products also use considerable amounts of water. Often the quantities of water needed in

some of the larger manufacturing plants are so great that the plant must install its own water and sewage systems.

Water as a Source of Power.—Before the steam engine came into use, innumerable small dams were built for the purpose of securing water power to turn water wheels, Fig. 140. The water wheels were used largely for operating sawmills and gristmills. In some places the water wheel was

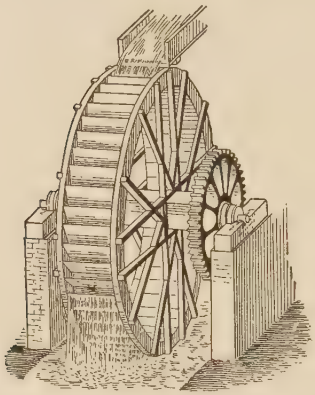


FIG. 140.—Overshot water wheel. (*From Tower, Smith, Turton, and Cope's Physics.*)

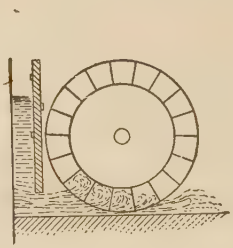


FIG. 141.—Undershot water wheel. (*From Tower, Smith, Turton, and Cope's Physics.*)

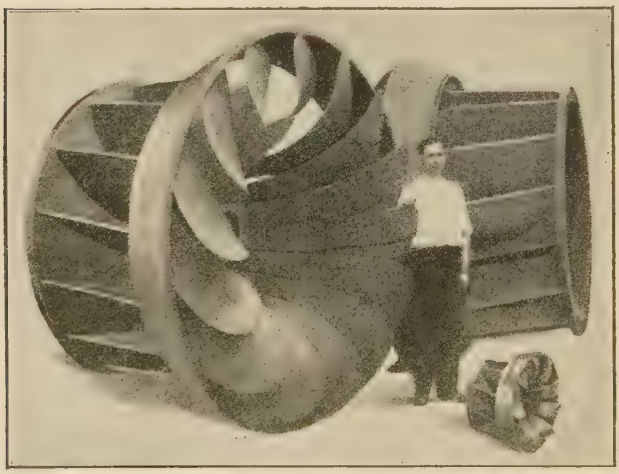


FIG. 142.—The runner of a turbine. (*From Tower, Smith, Turton, and Cope's Physics.*)

used to pump water or to operate bellows in the process of smelting iron from its ores. Beyond these uses the power of

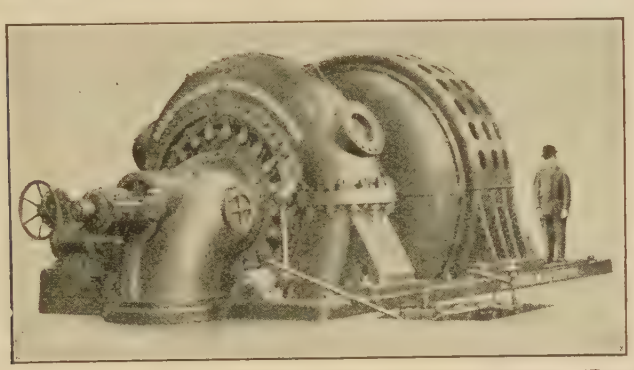


FIG. 143.—Turbine and generator of a hydro-electric power plant. (*From Tower, Smith, Turton, and Cope's Physics.*)

running water found little application. The old type of water wheel was not very efficient and was never able to use over

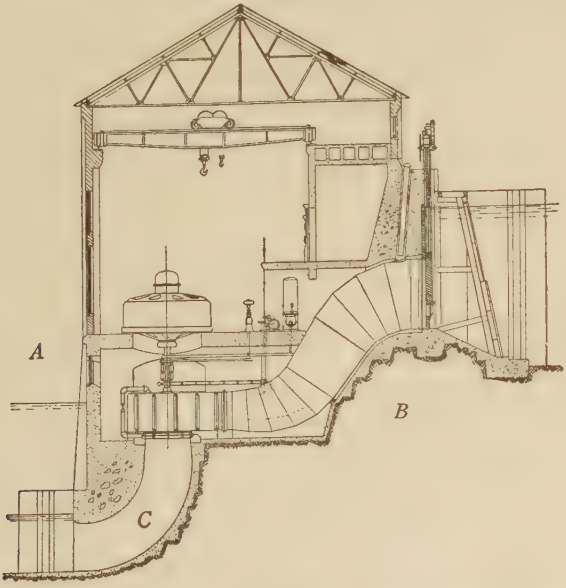


FIG. 144.—Diagram of hydro-electric power house showing a vertical turbine, *A*, with penstock, *B*, and tail race, *C*. (*From Tower, Smith, Turton, and Cope's Physics.*)

25% of the power of the water that passed by. With the invention of the steam engine and the use of coal as a fuel,

water wheels fell into disuse and neglect, with the exception of those in out-of-way places.

In 1827 De Fourneyron of France invented a new type of water wheel now known as the water turbine. The wheel of a water turbine resembles in many ways the wheel on a windmill, Fig. 142. The wheel of the turbine is enclosed in the pipe through which the water flows, and takes from the water about 90% of its energy. The turbine did not come into extensive use until the invention of a dynamo for producing electric currents came into use. Then it was found that the water turbine and the dynamo could be used wherever there was a waterfall or an elevated reservoir of water, Fig. 144. The turbine was connected to the dynamo, and as the water rushed through the turbine, the turbine wheel was made to turn and operate the dynamo. The dynamo generated electrical currents that could be carried many miles by means of wires to cities or to factories and there made to light lamps, drive cars, and operate all kinds of machinery. Thus it was learned that it made little difference whether a city was located near or at some distance from a water fall or other source of water power, for the water turbine and the dynamo working together were able to send the energy of the waterfall in the form of electricity to places where energy was needed to do work.

Since 1900, American engineers have been called upon to construct huge dams and reservoirs for the storage of waters and to install machinery for the purpose of using water power to do the work of man. And so today we find large volumes of water at Niagara being used to generate electricity to light distant cities, to move trains, and to operate the machinery in factories that are located far and wide from the falls. A dam across the Mississippi River at Keokuk, Iowa, furnishes power for cities located over a large area in the central west. In the Rocky and Sierra Mountains other great dams create reservoirs that provide power for a considerable number of western cities and their several industries.

Water and Transportation; Rivers, Lakes, and Harbors.— In early times the main trade routes of the world lay along the

water courses. In the early history of the United States much attention was given to the building of canals and locks and the improvement of water courses leading to inland cities. Here again the invention of the steam engine and the use of coal as a fuel turned the attention of people away from an important use of water. Railroads were built through the river valleys and along routes taken by canals. The railroads were able to deliver goods and passengers in shorter time and often at less expense. Thus the canals and improved water courses fell into disuse and were generally abandoned in many sections.

Now that the population of the country is demanding greater and cheaper transportation facilities, there is a revival of interest in the early methods of water transportation. Already in many places plans of reconstruction and reorganization are in progress. In districts where large amounts of coal, iron, manufactured materials, and food stuffs are being passed forth and back, canals are of vital importance.

The St. Lawrence River and the Great Lakes form one of the world's finest inland water systems. The river and its lakes provide a deep and fairly straight water course that leads 1700 miles into the interior of our continent. The course is interrupted by the Lachine and Sainte Marie rapids and the falls of Niagara. These obstacles have been overcome by a system of locks and canals, so that ships drawing 14 feet can pass directly from the sea to Chicago or Duluth. Transportation of vast quantities of materials is continually passing from port to port between such centers as Toledo, Buffalo, Detroit, Cleveland, Chicago, Milwaukee, Duluth, and many other centers of industrial activity. During three months of the year, ice closes some of the lake ports and shuts off communication with the sea. Otherwise the Great Lakes and the St. Lawrence serve as an example of one of the world's most perfect inland water courses.

New York City is the best example of a city which has grown up around a harbor. On the basis of population it is now the world's greatest city. In 1920 greater New York on the east side of the Hudson River had a population of five and one quarter million inhabitants. But if the adjacent towns in

New Jersey are counted in, the great industrial and commercial city, or group of cities about the bay, shows a total population of 7,500,000, inhabitants, which is several thousands more than that of London.

The harbor which made New York so great is one of the best in the world. The space in which ships may anchor runs from fifteen to twenty miles inland from the open sea and provides protection from waves and winds. The tidal effects are small. The channel into the harbor is straight and wide, and forty feet in depth at low tide, so that the largest ships may enter or leave at any hour. The port is never closed by ice nor greatly troubled by shifting sands. These advantages are not matched by any port on our coasts and perhaps not in all the world. A hundred years ago New York was of no greater importance than Boston, Philadelphia, Baltimore, or Charleston. But in those days a channel of ten feet was deep enough for the wooden vessels of those times. Now the ships are made of steel and iron, and are so large that New York is the only harbor that can meet the requirements.

Furthermore there is no Appalachian barrier between New York and the rich lands of all the west. The Appalachian barrier cuts off these vast resources from Baltimore, Boston, and Philadelphia. But for New York there is the valley of the Mohawk River, which serves as a pass to direct and guide the western wealth to Troy and thence down the Hudson valley to the ships of the world that meet in the wonderful harbor. Again, the people of New York constructed the Erie Canal with Buffalo at the Lake Erie end. This water course gave New York a water route to every port on the Great Lakes. To compete with the cheap water rates railways strove to reduce costs and to cheapen rates. All of this resulted in an abundance of freight materials for New York. On account of the large quantities of every kind of material, shipowners preferred the port of New York. This led shipowners to compete with each other and to give the port of New York the benefit of lower ocean rates. All of these benefits and privileges accorded to New York are the direct result of her harbor, the Hudson, the Mohawk River and its valley leading to the west, the Erie

Canal, the Great Lakes, and the Atlantic Ocean upon which are located the ports of the world. Transportation by water is the reason why New York has become the largest shipping point in the world, the leading commercial city and the largest manufacturing center in America, the world's largest center of population, and the money center of the western hemisphere and today of both hemispheres.

Water Wastes and the Necessity of Conservation.—Water is such a common substance, and its use is so closely related to all our necessities and comforts, that, like most common things, its importance is likely to be overlooked. Water appears in such an abundance in so many regions of our country that few people ever think of conservation in connection with the uses of water. As was stated earlier our individual needs are from three to four times those of European lands, and still our demands are for greater supplies. From all this a serious question arises—are we using our supplies to the best advantage? The communities are everywhere taxed to the limit to find sources of good water to satisfy the demands of their inhabitants. Are supplies of water being wasted in the home and in the industries of the community? In many places the water is pumped and put under pressure by the use of coal and steam or its equivalent. A waste of water means also a waste of coal.

In the home, wastes occur from wasteful methods employed in washing dishes and utensils, and in laundering. In city and town systems where the water is under pressure, one needs only to turn a faucet in order to be supplied. The ease with which the supply is secured is responsible for its waste. Thus in many operations two gallons are allowed to escape from the faucet when one might have served just as well. Leaking and dripping faucets often go unrepaired from one end of the year to the other. The loss of water from dripping faucets has been found to be anywhere from one gallon per hour to several gallons per hour.

In some homes the water is allowed to run during periods of cold weather in order to keep the water pipes from freezing, or in warm weather the water is allowed to run about pans

or bottles that contain perishable foods and dairy products. Each of the above cases illustrates wrong and wasteful uses of water. The water pipes that bring the water into the home should be placed at a depth that is beyond the freezing depth for the locality in which the home is located. The pipes that distribute the water about the home should be kept away from outside walls in which freezing may take place during the extremes of winter weather. To use water as a cooling agent is poor economy and inefficient. The amount of water used to keep perishable foods from spoiling is more costly and less effective than ice.

Excessive sprinkling of lawns and gardens, sprinkling at wrong hours of the day, spraying water upon automobiles and other vehicles in washing them, these and many more similar operations in which *excessive* amounts of water are used make the water problem a burden to the community. In this direction there should be no misunderstanding; water sprinkled upon lawns is not wasted when properly used. It is the *excess* over the amount actually needed that is wasteful. The total daily waste of water for any large American city is very large, and when figured by the year it is appalling. In many factories and industries needless quantities of water are continually being wasted. Such wastes add to the cost of the manufactured goods or cut down the return in profits to the manufacturing company. Waste of water means a waste of coal, wear on machinery, over burdened water systems, labor expense, high water rate, more frequent and unnecessary water shortages and famines.

In past ages people gave little thought to the conservation of their natural resources—coal, water, forests, soils, and the like. The present age differs from those which have gone before in the appreciation of the need of careful management of all the national resources that are so beneficial to our future national welfare. Already South Dakota has passed laws regulating the number of artesian wells and their rate of flow. Already the governments of cities are turning their attention toward problems concerned with the regulation of water uses and water distribution. Already the states and cities of the west have

entered into contracts and passed laws regulating and governing the amounts of the available water supplies and the various uses to which they shall be put. However, it remains for the individual and groups of individuals—commercial companies—to adapt themselves to these necessary regulations and restrictions. The study of the management of the affairs of the government and of the community with reference to the source of income, expenditures, and proper uses of natural resources of every kind has come to be appreciated as never before.

Projects

1. To make a study of the construction and operation of a water meter, and to learn the need of water meters in the home.

2. To make a study of the various kinds of water faucets and the principles underlying their operation, in order to be able to make renewals of worn parts in the water faucets of the home water system.

3. To make a study of the various kinds of water traps that may be employed in the drain pipes of the home in order to demonstrate the operating principles and the necessity of water traps in the modern methods of plumbing.

Suggestion.—In your demonstration or report make use of drawings in cross section of the various water traps that you study.

4. To learn how to remove grease and oil spots from clothing.

Caution.—Use only those solvents that are safe.

5. To make a study of the materials and methods employed in the manufacture of soap.

6. To make a study of soap in its relation to the removal of dirt and grease in laundry processes.

Suggestion.—(1) Demonstrate with a bottle that contains water and some oil. Shake and show how the oil and water soon separate into two layers. (2) Add some pieces of soap, shake again, and observe results. In which case was an *emulsion* formed? Is soap an *emulsifying* agent? Do the emulsifying properties aid in the removal of dirt and oils from clothing materials? Consult library articles on the purposes and uses of soap.

7. To make a study of the construction and operating principles of one or more typical forms of washing machines in order to learn how these machines aid the cleansing processes to take place.

8. To make a study of solutions, saturated solutions, and supersaturated solutions in order to learn the conditions necessary for the making of crystals of various substances.

Suggestions.—When you have informed yourself on the above subjects, display in airtight bottles the crystals of the various salts that you have prepared.

9. To make a study of the various types of water wheels.

Suggestion.—Construct a simple set of working models and display them in action. Show lantern slides of historic water wheels and their mills.

10. To make a study of the Pelton water motor and to compare and contrast its operating principles with those of the water turbine.

Suggestion.—Show pictures and drawings of each wheel and name localities in which each is used.

11. To make a study of *the locks* employed in canal systems for the passing of boats from one level to another in order to demonstrate the principles of operation.

Suggestion.—Display large and simply constructed drawings showing a system of locks in cross section.

12. To make a study of the history of the development of the Panama canal.

Suggestion.—All canals need water storages and water reservoirs at their highest point. Make this fact clear in the case of the Panama canal. Obtain lantern slides of locks and basin reservoirs, bird's eye views, etc.

13. To make a study of the geographical conditions relative to the Mississippi River in order to determine why this great river has not become one of the greatest water courses of the world for commercial transportation.

14. Debate. Resolved that Seattle, Washington, possesses better facilities for becoming the great metropolis of the west than does San Francisco.

UNIT IV

LIGHT AND ITS BENEFITS

CHAPTER XVI

SOURCES OF LIGHT

Object.—To make a study of the various sources of light that may be used for illuminating purposes.

Light Ministers to Our Comforts.—The boys and girls of today are so accustomed to brilliant lights in their homes, public buildings, theaters, and city streets that it is very difficult for them to realize that there was a time when the dwellers of the earth had no other light than that received from the sun, the moon, and the stars. Before man discovered fire and learned to make use of it, all of his activities were bounded by the sunrise and the sunset. Man feared the dark, and as the night approached he sought his home in the hillside cave in which he could better protect himself.

How wonderful must have been the bonfire and its uses! When it was built at the entrance of the cave or within the cave, the darkness of the dreaded night was driven back, savage beasts were held at bay, and the cold damp cavern home became dry and warm and full of light. The bonfire gave rise to the pine-torch, which enabled our ancient ancestors to go forth with a portable light. The use of pine-torches continued down through the ages, and until recent times it was in common use in northern Scotland.

As the state of civilization progressed, man found the pine-torch quite unsuited to his needs. Consequently we find various devices brought into service for the purpose of increasing both the quantity and the quality of light. Rushes were cut and dried and boiled in grease gathered from cooking meats or especially prepared for this purpose. An oil soaked rush one

yard in length burned for an hour or so. Later a short length of rush was placed upright in a bowl of oil or grease, and when lighted it gave forth a quality of light that was greatly superior to that given by the smoky flames of the pine-torch.

When solid fats and waxes came into use, the candle with its central wick displaced the torch and the oil-lamp with its wick of rush or moss. The candle gave a light of better quality, gave off less smoke and odor, burned more constantly for a greater length of time, and was more convenient and portable. The candle was universally regarded as a successful light-giving instrument, and by its means the activities of human life became more and more intensified. The work of the day could be extended into the hours of night, or in other words man was able to lengthen his day and shorten his night. The dark winter evenings were spent in preparing and working materials into clothing and instruments, or in planning and devising, or in family circles wherein the social hour led to the development of our present day arts and sciences.

The candle liberated man from the bondage of darkness and quickened his step in the march of progress. Then came the development of the kerosene lamp with its ten-fold increase in light-giving qualities. New uses for artificial light demanded still greater improvements, which followed quickly in the forms of gas and electric lamps. With these new forms artificial lighting effects were no longer limited to the confines of the home, but they were applied to the streets and highways in and about our villages and cities. Less than two centuries ago the streets of cities at night were infested with thieves and rogues who went forth under the cover of darkness to rob and to do bodily harm. In these days of well lighted villages and cities it is difficult to appreciate the influence that abundant illumination has toward securing the safety of life and property.

However, as in all the other good things that man has brought to his service, many evils have arisen from an excessive use of artificial light. The temptation of lengthening the day and shortening the night has grown out of proportion to the strength and capacities of our bodies. Nature has provided us with organs of sight wonderfully and accurately constructed, but

they are so delicately organized that any abuse of their use results in serious ills and greatly reduced efficiency. The demands upon the human eye have become enormous and are steadily increasing as the years pass. Again modern illuminants are more often wrongly than correctly used. The glaring lights of the home, the theater, and the church blind the eye-sight and cause nervous fatigue in place of comfort and relaxation. Light, like other necessities of life, serves us well when we employ it properly. Hence this unit of our work is concerned with light and the benefits that may be derived from its proper use.

THE SUN, MOON, AND STARS (HOME PREPARATION)

Object.—To make a study of the relationship of the sun, moon, and stars to the earth, and to study the lighting effects of each as observed upon the earth's surface.

MATERIALS.—Books and texts on astronomy. Magazines and other literature relative to the sun, the moon, and stars. Star map in Scientific American.

PROCEDURE AND OBSERVATIONS.—(*a*) The sun. What is the solar system? Draw a diagram of the solar system. What is the position of the earth in the solar system? The moon? Are there any stars within the solar system?

How far distant is the earth from the sun? How does the size of the earth compare with that of the sun? Does the sun give off light in all directions? Does the earth receive a very large part or a very small part of the total light given off by the sun?

With a lighted candle and a wire thrust through an orange demonstrate to yourself the cause of day and night; the cause of equal day and night; the causes of unequal day and night. Is the light given off by the sun accompanied by heat?

(*b*) The moon. What relationship does the moon bear to the earth? How far distant is the moon from the earth? How do their sizes compare?

Does the moon radiate or reflect light? Explain. What are *the moon's phases?* Where do we always see the new moon? Where do we view the moon as a semicircle or half moon? As a full moon? Is the light from a full moon great enough to cast a well defined shadow?

Why does a full moon appear to be enlarged when near the horizon?

Is moonlight useful for travelling purposes? Is the moon spoken of in literature and poetry?

(*c*) The stars. In order to locate the stars use the star map in the latest issue of the Scientific American Magazine.

From texts on astronomy learn the form of the star cluster popularly called the Big Dipper, Fig. 145. Locate the cluster in the heavens. By

means of the pointer stars in the outer edge of the bowl of the dipper locate *Polaris*, the polar star. Locate the Little Dipper, Fig. 145. The polar star forms one end of the handle of the Little Dipper.

The polar star is midway between the Great Dipper and a striking group of fine stars that resembles the letter "W." Locate this cluster and name it Cassiopeia's Chair.

FIG. 145.—Constellations of the northern heavens always above horizon in most parts of the United States. (*From Brownell's General Science.*)

On a night when the sky is clear and the moon is not in sight, study the wonderful river of light which foams across the sky. This great band of light is known as the "Milky Way," and it is a fine study when viewed with the aid of an opera glass.

Each of the star clusters bears a Greek name associated with some Greek legend or myth.

Is star light ever sufficient to cast a shadow? Is star light an aid to direction in ocean travel? In land travel?

Do stars shine by their own light or by reflected light?

How does the size of stars compare with the size of the sun?

THE CANDLE AND THE KEROSENE LAMP (HOME PREPARATION)

Object.—To study the principles underlying the construction of candles and kerosene lamps.

MATERIALS.—A pint can. Paraffin. Candle wicking or a suitable cord. A kerosene lamp. (Pupils who are unable to find kerosene lamps in their homes should study the kerosene lamp found in the school laboratory.)

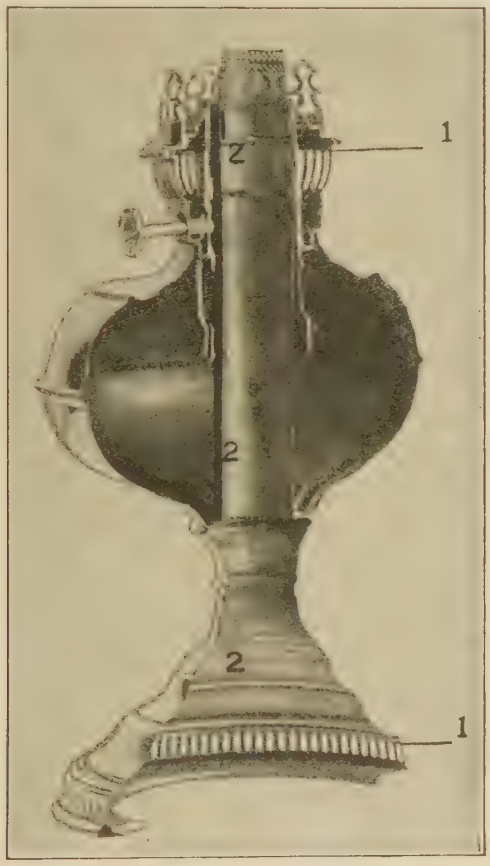


FIG. 146.—Sectional view of a round burner lamp. (1) Air vents that allow air to pass into the lamp and to the flame. (2) Central tube that conducts air to the inner surfaces of the flame. (*Courtesy of The Bradley and Hubbard Mfg. Co.*)

PROCEDURE AND OBSERVATIONS.—(*a*) The candle. Place several pieces of paraffin in the pint can. Set the can in a pan of hot water and allow the paraffin to melt. The melted paraffin should be at least two inches deep. Lower the string into the paraffin, and when it has become thor-

oughly soaked raise it into the air and allow the paraffin to harden. Again lower the string into the paraffin for a second or so, then raise it into the air to cool. Repeat the dipping process, until the candle has attained the proper thickness. If the paraffin is too hot or cools too rapidly, bring the water in the outside pan to the proper temperature by heating or cooling the water. The candle thus made is called a dip candle. In what other ways were candles made?

(*b*) The kerosene lamp. Remove the chimney. Carefully remove the burner from the bowl and thoroughly examine all of its working parts.

How is the wick raised and lowered? Is the wick wet with kerosene from bottom to top? How is it possible for the wick to convey the kerosene from one end to the other? Is the wick flat or round?

Is it possible for air to enter and pass upward through the burner? Look for the air vents and discover the places to which the air is conducted. Why is it necessary to admit air to the flame?

Put the burner back on the bowl of the lamp. Adjust the wick to a height which you think is proper. Light the wick. Observe the flame and again adjust the wick so as to give a flame that does not smoke. From where do the particles of smoke come?

Replace the chimney and again adjust the flame so as to give the best light. Hold a smoking taper or smoking brand near the base of the chimney. Does the smoke pass up through the burner and thence upward and out at the top of the chimney? Where do the fresh supplies of air enter the lamp? Where does the stale air leave the lamp? Does a lamp consume the air of the room? Does a burning lamp give off carbon dioxide to the room? Does an ordinary kerosene lamp use up as much air of the room as a person does? Do soot and particles of carbon settle on the inner surface of the chimney? Do particles of soot and carbon leave the lamp and settle on household furnishings? Should a room be ventilated in which lamps are burning?

GAS LAMPS (CLASS DEMONSTRATION BY TWO OR MORE STUDENTS)

Object.—To make a study of the two types of gas illuminants—flames from "tips" and burners with gas mantles.

Apparatus.—Common clay tip burner mounted in brass holder and connected with a source of gas. An improved type of gas lamp provided with a gas mantle and chimney. The lamp should be mounted and means provided for connecting it with a source of gas.

Procedure and Observations.—(*a*) Clay tip burner. Light the burner. Study the flame at three different heights. Adjust the flame to give the best light. How does the amount of light compare with that of a candle? With the flame of a flat burner kerosene lamp? With the flame of a round burner kerosene lamp? Does soot and smoke fly from

the flame and settle on the furnishings of the room? Does the flame consume the oxygen of the air in the room? Should the room be ventilated?

(*b*) The gas mantle type of lamp. Remove the chimney. Carefully remove the mantle without breaking it. Remove each part of the lamp until nothing but the base with the regulating device remains.

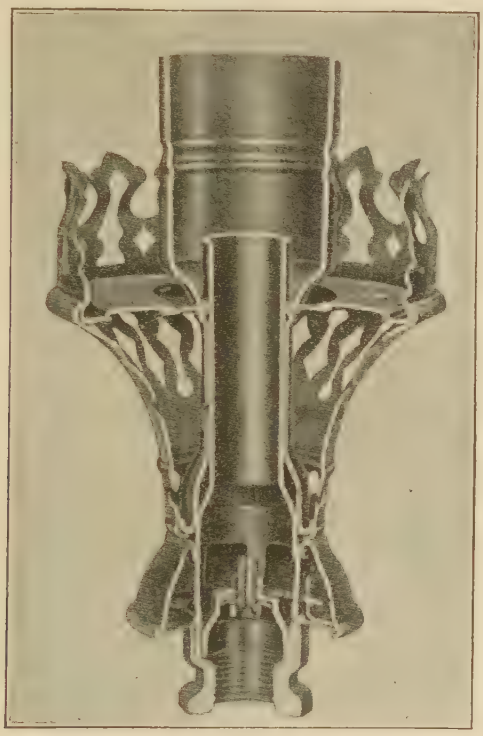


FIG. 147.—Sectional view of modern upright burner. (*Courtesy of the Welsbach Co.*)

Turn on the gas and show how the regulating valve adjusts the supply of gas. Hold a burning taper above the escaping gas and show again how the regulating valve adjusts the gas and the height of the flame.

Slip on the tube or air mixing chamber and again turn on the gas and make adjustments. Call attention to the fact that the flame is nonluminous and very hot. Close the holes at the bottom of the air mixing tube and call attention to the luminous and smoky flame. Adjust the dampers at the bottom of the tube so as to give the best possible nonluminous flame.

Turn out the gas. Replace the gas mantle. Turn on the gas, light, and adjust height of flame too high, too low, and finally make adjustments to give the best light.

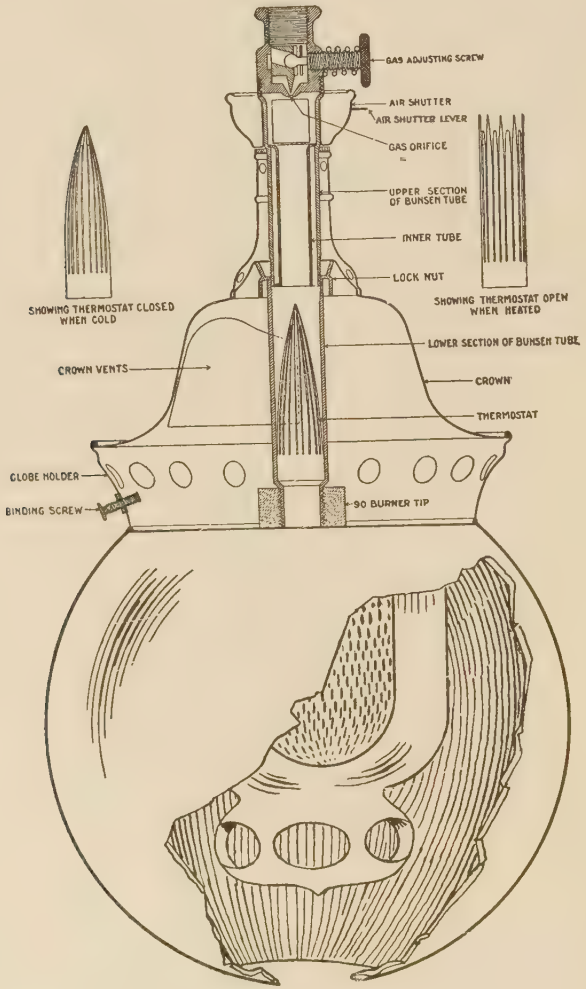


Fig. 148.—Sectional view of modern reflex lamp. (*Courtesy of the Welsbach Co.*)

Turn out the gas. Replace the chimney. Light and adjust to give the best light.

Compare quality and quantity of light with that given out by the candle, the kerosene lamp and the clay tip burner.

Does the lamp consume the air of the room? Does the gas lamp give out a great deal of heat? Is the quantity sufficient to make a room uncomfortable in summer time?

How does the cost of the light-giving qualities of this lamp compare with that of candles, kerosene lamps, and gas tip burners?

Is the gas mantle lamp a good lamp for illuminating homes, shops, stores, streets, etc.? Is it so used?

ELECTRIC LAMPS

Object.—To make a study of the construction and light-giving qualities of various types of electric lamps, and to compare the advantages and disadvantages of this type of lamp with those of lamps thus far studied.

Apparatus.—Electric light globes having carbon, Mazda, and tungsten filaments.

Materials.—Three or four dry cells. Three or four kinds of wires of the same diameter, preferably, #30 German silver, #30 steel wire, and #30 copper wire. #18 cotton-covered wire.

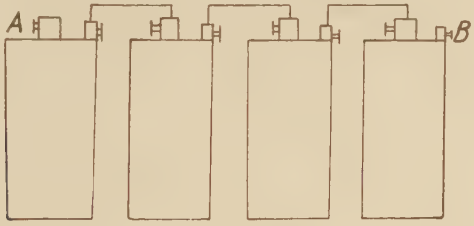


Fig. 149.—Dry batteries connected in series.

Procedure and Observations.—1. Using six inch-lengths of #18 copper wire, connect the batteries in series as shown in Fig. 149.

2. Using 12 inches #30 copper wire, join binding post *A* with *B*. Does the wire get hot and then incandescent—giving off heat and light? Repeat with a longer piece of #30 copper wire. What are the results? Repeat with a shorter piece of #30 copper wire. Results?

3. Repeat with #30 German silver wire. German silver offers greater resistance to the flow of the electric currents than does the #30 copper wire, and so only the shorter pieces of German silver wire allow enough current to pass to heat them to incandescence.

4. Repeat with lengths of steel wire.

5. Wrap some cotton thread about a short length of copper wire and pass the current through. Does the thread burn? Do hot electric light wires sometimes set houses on fire? Is there danger of fire when we use small wires to carry large currents of electricity? Is there danger of heating wires of any size, when we draw too great amounts of electricity?

6. Examine a carbon filament lamp, Fig. 150. Where does the current enter and leave the lamp? Screw the lamp into an electric light socket.

What causes the filament to become incandescent? Why is the most of the air removed from the globe? What happens when air is allowed to enter the globe while the lamp is lighted?

How does the light compare with the light of the flame of a candle? With other flames? With the light given off by the gas mantle?

7. Repeat 6 using a tungsten or a Mazda lamp or both.

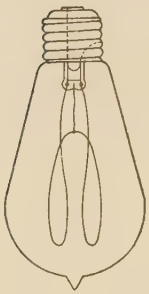


FIG. 150.—A carbon filament incandescent lamp. (*From Tower, Smith, Turton, and Cope's Physics.*)

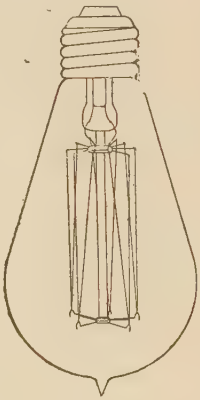


FIG. 151.—A tungsten lamp. (*From Tower, Smith, Turton, and Cope's Physics.*)

8. Do these lamps consume the air of the room? Do they give up as great amounts of heat as the flames of the kerosene lamp or hot gas mantles? Do they give off odors and particles of soot and smoke? Are electric lights more convenient than the other forms of light? Are there any disadvantages arising from the use of electric lights? If so, name them. How does the cost of electric lighting compare with other forms of lighting?

THE HOME LIGHTING SYSTEM

Object.—To make a study of the parts of the electric-light wiring system in the home.

PROCEDURE AND OBSERVATIONS.—1. Where do the electric light wires enter the home? How are the wires protected as they enter the home? Are they covered or bare? Why? What is an *electrical insulator?* Is there danger from poor *insulation?*

FIG. 152.—An enclosed fuse. (*From Tower, Smith, Turton, and Cope's Physics.*)

2. When the wires have entered the house do they pass to a meter and then to a fuse box?

3. Study the dial of the meter. Do you read it in the same manner as you do the dial on a gas meter? Turn on one or more lights and observe any movement on the part of a white metallic disc that is usually dis-

played under a glass window on the face of the meter. Turn on two or more lights. Does the disc rotate more rapidly? What is the need of a meter?

4. Trace the wires from the meter to the fuse box. Do both wires enter the fuse box? Why? How many wires leave the fuse box? Is there a fuse plug for each wire that leaves the box? What is the purpose of a fuse plug? Examine the construction of a fuse plug. Is it labeled or marked in any way that tells how many *amperes* of current may be used before it "blows out?" Is it dangerous to use large fuses where only small ones are intended? Reason?

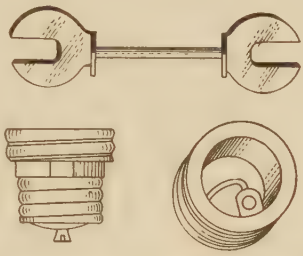


FIG. 153.—A link fuse (above); plug fuses (below). (*From Tower, Smith, Turton, and Cope's Physics.*)

5. Is there a switch near the fuse box or in the fuse box? When may such a switch be of good use?

6. Are the wires that lead away from the switch box well insulated? Do the wires pass through partitions and floorings in order to pass to rooms above or below? Are these wires heavily insulated? When the wires run through walls or boards or partitions are they provided with porcelain insulators? Why? Are any of the wires exposed and bare?

7. How are the wires passed to the various lamps of the several rooms? Are there two wires passing to each lamp? Reasons?

8. Are there push buttons and switches for turning off and turning on the lights? Ask your instructor to show you a model push button or switch. Examine it and observe how it operates.

9. What are the safety first rules concerning electric wires and anything that might come into contact with them?

10. What provision does the city government provide for the inspection of wiring systems in homes, shops, and factories? Is such inspection necessary?

The Sun, the Source of Heat and Light.—So accustomed have we become to the presence of the sun that few of us ever consider its great importance. The work that it daily performs is beyond the comprehension of the human mind. In his book, "The Study of the Sky," Howe sums up the work of the sun in the following words:

"Without its steady gravitational pull on the earth our planet would fly away to unknown regions of space, and the chill of death would settle down upon it. The oceans would stiffen into glass; the rivers would halt in their courses. All

the higher forms of vegetable life would wither and die, and humanity would perish of hunger and cold. For the human race is dependent upon the energy which the sun radiates so lavishly.

"The sun stimulates the growing plant to disengage carbon from the embrace of oxygen, feeding on the carbon and leaving the oxygen, which is necessary for the life of men and animals. Its heat evaporates the waters of the oceans, which rise, form clouds, and descend again as rain or dew, quenching the longings of the parched earth, nourishing vegetation, coursing in majestic rivers to the sea, refreshing the bodies of men and animals, and giving delight to all intelligent spirits.

"The energies of the sunbeams were stored ages ago in primeval forests: the forests were overwhelmed by the mighty deep and buried in a sepulcher of stone. Today men dig up the mummified sunbeams and burn them in their furnaces and fireplaces. The genial light of the grate fire is due to those ancient sunbeams which are now released from their prison house. The flying locomotive gets its speed from the sunbeams. . . . The water which flows into our houses has been purified by the sun's rays, and has been forced through the pipes by great engines which derive their power from solar energy stored in coal. The electric car is driven by a current generated by a dynamo, and the dynamo in turn by a steam engine which is fed with sunbeams of bygone ages. The electric light, which turns night into day, is stray sunshine. Nearly all the heavy work of the civilized world is done by the sun.

"Bread which is the staff of life, comes from the wheat which has been stimulated in its growth by sunbeams, and moistened by water lifted by the sun. If the mill which reduced the wheat to flour was driven by the wind, we find the source of the wind in heat produced by the sun's rays. If the mill was driven by water power or by steam, we shall say that the sun supplied the power which turns the millstones. Even the final process of baking the bread is an application of heat originally derived from the sun. A man's muscles obtain their strength from the food which he has eaten: in the food has been stored the energy of the sun.

"In fine, we owe to the sun the substance of our bodies, the maintenance of our physical energies, the comfort which we enjoy, the cooling breeze, the gentle shower and manifold beauties of nature."

The Distance and Size of the Sun.—Every day men are measuring the speed of moving trains, racing automobiles, flying airplanes, or the flight of bullets and projectiles. Scientists have worked out wonderful and extremely accurate methods for determining the speed of light, of electricity, of the ether waves in wireless telegraphy, and of motion of every sort. The speed of light has been found to be nearly 186,000 miles per second. Astronomers have found that light requires very close to 500 seconds to come from the sun to the earth. Therefore the distance of the sun is obtained by simply multiplying the speed of light by the time required to make its flight to earth, and when this is done the distance is found to be 93,000,000 miles.

The distance around the earth at the equator is 25,000 miles, and the people who live at or near the equator are carried this distance every day. If it were possible for one to travel directly toward the sun at the rate of 25,000 miles per day, it would require a continuous journey of 3700 days or 10 years to traverse the distance between the earth and the sun.

Knowing the distance of the sun it is not a very difficult problem of elementary mathematics to calculate the diameter of the sun. Calculations from various measurements show its diameter to be 866,000 miles or about 110 times the earth's diameter. From the diameter of a ball we can figure its size, and so in the same way it is found that the sun is 1,300,000 times as large as the earth. If the sun were hollow, and the earth were placed at its center, the moon would have room and much to spare in which to follow its usual orbit about the earth.

The sun radiates its heat and light in all directions, and thus it is seen that the earth receives as its share an exceedingly small amount of the total that is sent forth into the depths of space. There is, indeed, streaming forth from the sun 2,200,000,000 times as much heat and light as the earth receives.

The Moon and Reflected Light.—Of all the celestial bodies that take their way across the heavens, the moon has played the part of mystery. The moon was thought to exercise a

FIG. 154.—A telescopic photograph of the moon one day after first quarter.

considerable influence on every earthly affair. It was believed that it affected the weather for good or for ill, that it determined the planting and harvesting of crops, and that pigs must

be killed and the timber cut at the right time of the moon. Many tales of magic, witchcraft, and popular delusions of every sort were in some way associated with the appearance or the absence of the moon. Even one of our common words, lunatic, means moonstruck—a person upon whom the moon shone while he was sleeping. Historic writings and monuments testify that the moon was considered in religious rite and ceremony. It is quite possible that had the moon appeared night after night in the heavens with the same regularity that the sun shows during the day, a good deal of the mysticism connected with the moon might not have developed in the minds of men. Even today there is a widespread and popular notion that in many ways the moon exercises a great deal of influence over the lives of men, animals, plants, and other terrestrial affairs. However, there is not the slightest scientific basis for these absurd practices and beliefs, and, as people become better informed, they see the moon in its true relationship to the earth.

A boy or girl playing with a mirror is able to reflect the light from the sun into the dark corners of a room. In the same manner the moon reflects the light of the sun toward the earth. Unlike the sun, the moon is a cold body and is, therefore, unable to radiate heat and light. Like the earth, it has a *day hemisphere* and a *night hemisphere*. The day hemisphere is the portion turned toward the sun, and the night hemisphere is the portion turned away from the sun. When we see the moon in the west in the early evening, the day hemisphere is so turned away from us that we are able to see only a small part of the lighted portion. This view gives the moon the appearance of a crescent and is known as the new moon. Those evenings on which we see the moon rising out of the east, its day hemisphere is turned full toward us. This view of the moon gives it the appearance of a disc and it is known as the full moon.

Whether we have a new moon, a full moon, or any other phase of it, depends upon the position of the sun and moon in the sky. When the sun and the moon are both in the east, we have a new moon in the morning. When they are both in the west, we have a new moon in the evening sky. However, when the sun appears

in the east and the moon in the west, a full moon is observed in the morning. With the sun in the west a full moon is seen in the east during the evening and night. As the moon and the sun vary these positions, the different phases of the moon are observed. During a new moon the dark hemisphere is also dimly visible. This is because the earth also plays the part of a mirror and reflects back a portion of the sunlight which it receives. Some of this reflected sunlight lights up the dark side of the moon so that we can see it. This phenomenon gives rise to the saying, "the old moon in the new moon's arms."

The moon is 240,000 miles distant from the earth. Hence its orbit about the earth has a diameter of 480,000 miles. It encircles the earth once in every 27⅓ days—that is, it takes the moon 27⅓ days from the time it leaves a fixed star to return again to this same star. But the time from one new moon to the next, or from the sun around to the sun again, is 29½ days. The reason for this is that the sun has changed its place among the stars, and so it takes the moon an extra two days to catch up in order to be in line with the sun and the earth. The period of 29½ days is called a *lunar* month. Each and every day the moon rises 51 minutes later than the preceding day. Since the solar day is 24 hours long, the lunar day is 24 hours and 51 minutes long.

The moon is of service to man in many ways. Its light relieves the darkness of the night and thus adds to the safety and comfort of life. As it moves across the face of the sky it becomes a timekeeper by which the master of an ocean going vessel may determine his longitude and correct any error that may arise through a faulty chronometer. For the master of every vessel carries pilot charts and the Nautical Almanac which gives the position of the moon among certain fixed stars at given Greenwich times for each day of the year. The navigator of the ship by means of a sextant measures the distance of the moon from one or more of the fixed stars and thus determines the true Greenwich time.

The moon is the chief cause in the production of tides, which at their flood lift vessels over harbor bars and thus allow the vessels to bear their burdens farther inland to protected wharves.

The harbor of Liverpool communicates with the ocean by a narrow channel, through which hundreds of millions of tons of water rush out every six hours during the ebb of the tide and wash away the debris and silt which would choke the narrow entrance. Without the tides Liverpool would lose its large volume of commerce and would no longer be one of the world's greatest ports. Many attempts have been made to harness the tides to various kinds of tide machines in order that the energy of the tides may be put to work turning dynamos that would produce light and power. Should this ever be done, the moon would be brought directly to the service of man—driving his mills by day and lighting his cities and homes by night.

The Stars, the Time Keepers.—The stars are those fixed and brilliant points of light which shine forth from the depth of space. As nearly as the unaided eye can judge, the fixed stars remain in the same relative position year after year and century after century. Prehistoric man, Homer of ancient Greece, and David guarding his sheepfold, all saw Orion and the Great Dipper much as we see them today. For the most part the stars shine with an unvarying brilliancy and thus present an ideal of eternal constancy.

There are two kinds of stars—the fixed and wandering. The wandering stars are the planets of the solar system. They are worlds very much like the earth. They revolve about the sun and receive the sun's light and heat which they reflect much in the same way as does the earth. With the earth there are eight planets—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Jupiter and Venus usually appear brighter than the brightest of the fixed stars. Since the planets revolve about the sun, they are continually changing their position in the sky. It was for this reason that the ancients gave these bodies the name *planet*—"wanderer." These planetary stars look very much like the fixed stars except that they do not twinkle.

The fixed stars, or more simply stars, are suns that radiate light in precisely the same manner as does our sun. These great suns are at such amazing distances from us that their motions seem exceedingly small. Our nearest star neighbor is

Alpha Centauri, which is 275,000 times as far away as the sun. Sirius is twice as far away, and light requires eight years to come from it to us. The pole-star shines by light that left it over fifty years ago. The entire body of stars gives about one sixtieth as much light as a full moon. Starlight, however, decidedly lessens the darkness of the night. No star sends to us a measurable amount of heat.

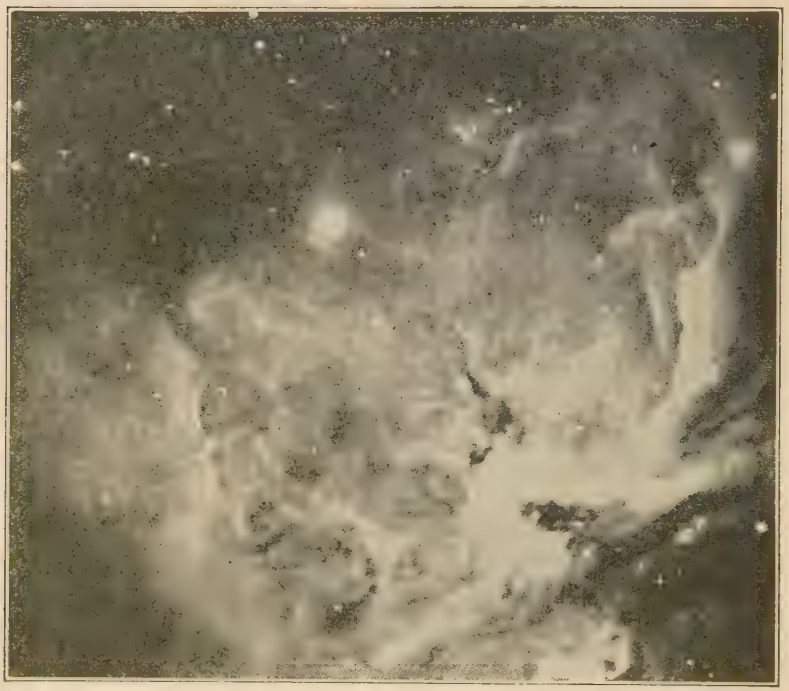


FIG. 155.—The Great Nebula and star cluster in Orion. Photograph taken by means of the 100-inch Hooker telescope at Mt. Wilson. The light from this nebula requires more than 300 light years to reach the earth. (*Courtesy of the Monthly Evening Star map.*)

In this busy day and age, when more importance is attached to a minute than was formerly given to an hour, when men are more considerate of hours than their forefathers were of days, the necessity for accurate time is realized as never before. The belated traveler who finds himself "thirty seconds late" hurries in vain to the depot to find that the train has already pulled out. Engineers and scientists dispute about tenths and hundredths of a second, while the people of the world wonder

how they contrive means to measure intervals of time so minute. The daily doings of man are regulated to a large extent by the timekeepers that are found everywhere for sale, but few people ever make inquiry as to the authoritative source of time and the methods employed to obtain a standard time.

In a general way the average person has an idea that the astronomer observes the sun when crossing a meridian and thus regulates and adjusts his clocks. The earth on its journey around the sun causes the sun to have an apparent movement among the stars. This apparent movement of the sun is about a degree per day, and it is easily seen that the rotating earth will have to turn farther in order to carry any particular meridian from sun to sun again, than to carry it from a star around to the same star. The time from sun to sun marks the length of a *solar day*—sun day. The time from a star around to the same star marks the length of the *sidereal day*—star day. From what has been said, it is seen that the sidereal day is shorter than the solar day. Since the fixed star never changes its relative position in the heavens, the astronomer finds it very convenient to mark time by the stars rather than from the sun. Consequently astronomical clocks are so made and regulated that they show always the same hour and minute when the stars come back to the same place. Such clocks are sidereal clocks.

The sidereal clocks are corrected by comparing the time at which the right ascension of the hour circle of a given fixed star coincides with the meridian at which the correction is to be made. For example, when Sirius is "on the meridian" the sidereal time is exactly 6 hours and 40 minutes, and if the sidereal clock at this moment shows 6 hours, 39 minutes, and 58.5 seconds, the astronomer knows that his clock is exactly 1.5 seconds slow. The correction is made, and the sidereal time is changed over to true solar time. The observatory clocks are connected by means of telegraphic wires with thousands of other electrically operated clocks in all parts of the country. Every hour every clock is automatically corrected by electrical impulses sent out from the master clock at the observatory. Thus, in short, the stars of the heavens are the time keepers and time regulators of the affairs of men.

The Necessity of Artificial Light.—No other animal on the face of the earth is so dependent upon light as is man. This is largely due to the fact that man lives by using and matching his wits against the forces and agencies found in nature. If he wants a fish or a bird or an animal, he finds that the fish swims swiftly, the bird quickly takes flight, and the animals are stronger or more fleet. To catch any of these forms for the purpose of food and clothing, he finds his hands poorly armed with sharp claws, his teeth enclosed in a mouth too small for seizing prey, and his legs out-distanced by those of fleeing animals. In order to obtain these forms for food and clothing he must use his intellect. He must shape a fishhook, perfect a spear, manufacture a bow and arrow, contrive traps, and use whatever means his intelligence prompts him to use. However, to do all this during the hours of sunlight takes time which should be spent in search of food and pursuit of game.

The discovery of fire was, perhaps, first used for warmth and comfort and protection from animal dangers that infested the night. But it was not long before man found that, by the aid of his camp fire, he could extend the work of the day into the hours of the night. As he became more and more skilled, his intelligence grew. A growing intelligence awakens in its possessor a desire to do better and more exacting work. In order that labors might be better performed, more light in the cavern home was necessary. Firebrands were set upright by placing their lower ends in holes in the clay floor, or fires were built on elevated stone shelves or cavities in the wall. These elevated fires lighted up the early home in a better manner than did those placed upon the floor. In order to make the firebrand burn longer and with better light-giving qualities, it was saturated with animal fats. Then followed the clay bowl with plant and animal oils from which extended wicks of moss or plant fibers. Each new form was an improvement over that used before. The new forms gave a more constant and dependable quality of light. They were portable and could be placed in advantageous positions in the home or carried forth in search and quest of materials or other purposeful pursuits. Thus artificial light came into use.

Oil Lamps, Candles, and Candle Sticks. As the state of civilization progressed, the rude bowls of the first oil lamps became more and more artistically designed and decorated. The ancient Etruscan lamp is exquisite in form and materials. Since no better quality of oil nor more improved wick was used in the Etruscan lamp than was used in the earlier bowls, the quality and quantity of light remained about the same. For centuries the lamp makers of the various ancient and mediæval nations devoted their time and study to the creation of various forms and decorative schemes for the bowls of these oil lamps. The idea of improving the oil and inventing a better wick or burning device did not receive a great deal of thought and attention. While the rich used lamps whose bowls were made of gold and silver, their homes were little or no better lighted than those of the poorer people who used lamps fashioned from clay or metal.

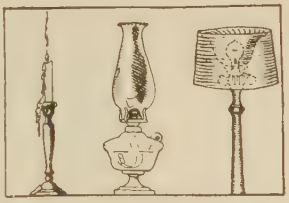


FIG. 156.—Three sources of artificial light that tell the story of the achievement and progress that was made during the 19th Century.

When solid fats and waxes came into use, the candle with its central wick displaced to a large degree the oil-lamp. The materials used in the candle were chiefly tallow, sperm-oil, spermaceti, beeswax, vegetable waxes, and paraffin. These fuels are solid and are melted to a liquid form by the heat of the candle flame before they are consumed. The candle is an ingenious device in which the fuels are kept in the solid state until just a few moments before they are actually required by the flame. In such an arrangement there is nothing to spill, or to break, or get out of repair. When the candle is lighted, the heat of the flame forms a cup on the top of the candle. So long as the candle burns, this cup is full of oil which supplies the wick upon which the flame is burning. In short, a burning candle is an oil-lamp that makes its own bowl. Irregularly shaped candles cannot make perfect oil cups under their flames, and consequently melted oils run down the sides of the candle. Such candles burn badly and have smoky flames. Those

candles that are made from good grades of wax give a light of excellent quality and little odor, and are quite free from fumes. Candle sticks came into use, and here again the lamp makers of the world gave a great deal of time and attention to the creation of candle holding devices.

The candle was regarded for many centuries as a successful light-giving instrument, and by its means home life became more and more intensified. The evenings were spent in the family circle in which reading, planning, devising, games of wit, and social intercourse developed the family ties and interests in a multitude of ways that would be difficult to enumerate. The candle was the only source of artificial light in use in colonial days and was in general use during the days of the Civil War. It is still found in homes, where it serves as an emergency measure when other sources are temporarily out of use.

Fig. 157.—Shooting an oil well.

The Discovery of Petroleum; the Kerosene Lamp.— Up to the middle of the last century the world depended upon plants and animals for all supplies of oils and fats. Whale oil was the most important of the lubricating oils, and in many places it was used in whale-oil lamps for lighting purposes. By 1850 whale oil had become expensive because of the scarcity of whales. Sometimes a whaler had to spend from one to two years in the northern seas before obtaining a full cargo of oil. As a result the oil sold at such high prices that most people had to give up its use. At its best whale oil was not a good oil either for lamps or for lubricating purposes. The finding of petroleum in abundance, together with the discovery of ways of

refining it, gave the people a substitute which was much cheaper and better than whale oil.

Crude petroleum as it comes from the ground is an oily liquid, ordinarily thick and dark brown in color, but in some cases it is thin, and sometimes light in color. The early colonist knew of the existence of petroleum from the Indians from whom they learned its use as a medicine, especially as a liniment for rheumatism. For these reasons it was called Indian or Seneca oil. A few natural oil springs supplied all that the colonial settlers needed for medicinal purposes. Attempts were made to use the crude oil for lighting purposes, but it was found to give such smoky flames and disagreeable odors that the attempt was abandoned and the oil considered worthless. Hence, it was really not the discovery of petroleum itself, but the discovery of methods of refining it that made it suddenly important and of great value.

In 1846 a man named Gesner distilled from coal an oil that burned well in lamps. Soon after this a Pittsburg druggist, Samuel Keir, succeeded in distilling from petroleum a satisfactory oil for lamps. This practice became widespread, and soon there was a demand for refined petroleum oil.

Petroleum is found stored in the pores of porous rock which are overlaid with layers of nonporous rock. These nonporous rock layers, that cover the oil bearing layers, keep the oil from rising to the surface and escaping by evaporation. To reach the supply of oil a hole is drilled through the overlying layers. In 1859 the first oil well in the United States was sunk near Oil Creek in Pennsylvania by a man named Drake. After many attempts to reach an oil-bearing rock, he finally succeeded. When his drill struck the oil-bearing rock, the oil filled the drill hole and overflowed the surface of the ground about his drilling machine. His discovery produced a great deal of excitement, and people rushed to the Pennsylvania oil fields in search of oil and wealth. In the next few years many wells were drilled, oil was produced faster than it could be refined into useful forms, and consequently much was wasted.

In order to refine the crude petroleum it is placed in large iron stills which hold from 500 to 1000 barrels. The oil is heated

by pipes through which steam is circulated. The first two products vaporize at very low temperatures, 104°F. and 158°F. They have peculiar chemical names, cymogene and rhigolene, and are used in hospitals as petroleum ether. When these products have passed off and are collected, the temperature of the oil is raised and kept between 158°–176°F., at which point light gasoline passes over. Again the temperature is raised and kept between 176°–248°F., when heavy gasoline passes over. Between temperatures 248°–302°F. naptha is obtained. At

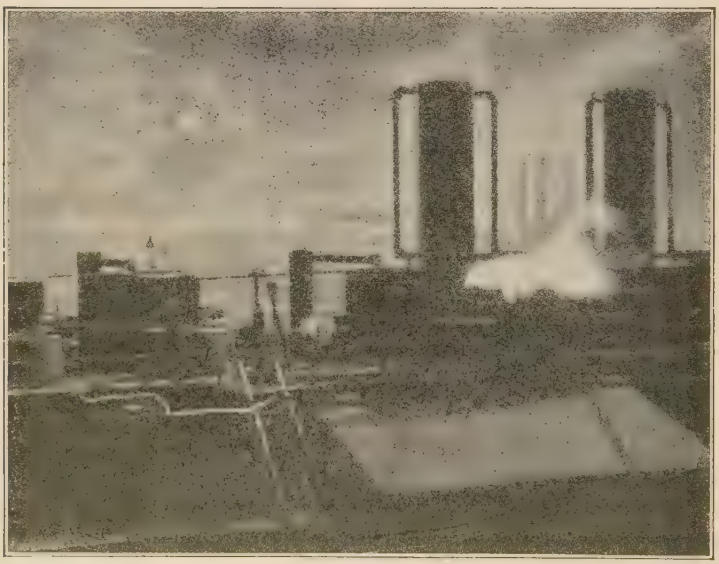


FIG. 158.—Stills in which crude petroleum is roughly separated by fractional distillation into illuminating oils, fuel oils and tar.

302°–576°F., kerosene or illuminating oil is freed. The thick tar that remains in the still contains the heavy lubricating oils and paraffin. From this residue come many valuable products which are some 200 in number. Before the gasoline and kerosene are placed upon the market, they receive further chemical treatment in order to be freed of impurities.

In Chapter VI the conditions necessary to luminous and non-luminous flames were pointed out. The kerosene lamp is simply an arrangement for the production of a luminous flame,

and in simplicity of construction it is next to the candle. The three essentials are a reservoir, a wick, and a burner bearing a glass chimney. Capillary action in the wick transfers the oil in the reservoir to the flame on the burner. The kerosene oil is a hydrocarbon which, when vaporized, is broken down by the flame into the two fuel elements—hydrogen and carbon. The hydrogen, being more combustible than the carbon, combines with oxygen and releases a great deal of heat. The carbon particles are heated to incandescence and radiate considerable light. These particles of hot carbon would pass off as soot and smoke if quantities of air were not admitted at the base of the burner. And so when the flame is adjusted to the proper height, the quantities of air passing through the burner openings are sufficient to burn the carbon to carbon dioxide.

The "Rochester" burner is so constructed as to require a cylindrical wick instead of the usual flat wick. The cylindrical wick provides for a large flame confined in small space in which the heating effects are greater and the lighting effects are increased. A central air chamber conducts air to the central parts of the flame, and thus combustion of the escaping particles of carbon prevents the release of soot and smoke when the flame is adjusted to its air supply. In any lamp the hot gases and stale air escape from the top of the chimney and into the air of the room. Small lamps may remove as much oxygen from the air as one or two persons, while the larger varieties may consume as much as six to ten people. Rooms in which open flames consume the air should be properly ventilated.

Gas and Gas Lamps.—In one of the experiments (Chapter VI) the destructive distillation of wood and coal indicated how illuminating gas could be manufactured from these substances. This method of producing gas seems to have been discovered and put to use for illuminating purposes as far back as 1800 by Wm. Murdock, an Englishman. He designed and installed gas plants for illuminating purposes in several of the English cotton and woolen mills. For his achievements the Council of the Royal Society awarded him the Count Rumford medal and proclaimed him entitled to an honorable place among the torch-bearers of civilization.

Naturally Wm. Murdock had many difficulties to overcome in perfecting his gas plants. For many years the gas was burned as it sprung forth under pressure from very small holes that were drilled in the ends of the iron gas pipes. These simple burners were often improved by varying their shape and form. Finally a flattened pipe with a narrow slit in its end

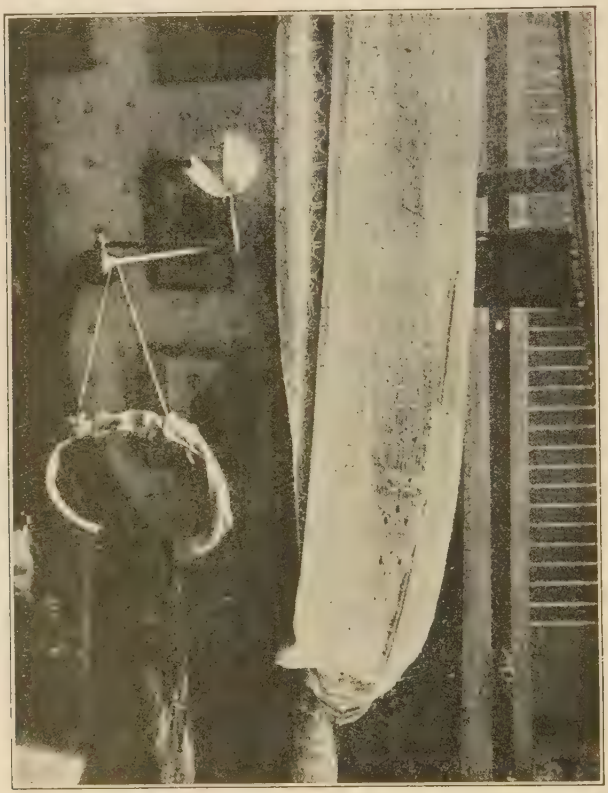


FIG. 159.—Gas burner of the clay tip type mounted on a swing bracket. If used as shown in the illustration it presents three very grave hazards to life and property. Point them out and suggest remedies that would correct the hazard. (*U. S. Bureau of Standards, Circular No.* 75.)

came into general use. The flat flame of burning gas from such a source has the shape of a fish's tail, from which the burner gets its name—fish-tail. The iron materials of the burner conducted away a great deal of heat from the flame and thus lowered its light-giving qualities. To prevent this trouble clay

burners, later called clay tips, were invented and stuck into the end of the pipe. Where people do not see the need of using a better form of gas lamp, this simple device is still in general use.

While the gas flames provided a cheaper, a better, and a safer means of illuminating factories and homes, as well as of making it possible to light nightly the streets of cities, there was a constant desire that the flame be made in some manner more luminous. Late in the last century Carl Auer Von Welsbach heated pieces of cotton saturated with the salts of cerium and thorium, and found that the ash which remained retained the appearance and form of the piece of cotton fabric which he had heated. He also found that this ash or oxide of the metals glowed brilliantly when held in the flame of a Bunsen burner. This gave him an idea. He produced a mantle made of cotton, saturated it with the salts of thorium and cerium, placed it over the flame of a Bunsen burner, and allowed the heat of the flame to burn away the cotton and to convert the salts of the metals to oxides. By adjusting the flame to the size of the mantle of oxides thus formed, he found that the mantle glowed with great brilliancy and gave off an abundance of light of a wonderful quality. In 1885 the mantle and a special form of burner were placed upon the market. Improvements were made, and today the market is provided with mantles of greater strength and still greater light-giving qualities.

FIG. 160.—Early type of gas lamp for mantle. (*Courtesy of the Welsbach Co.*)

The gas lamp that employs the gas mantle is simply a modified Bunsen burner provided with a needle valve for a close adjustment of the gas supply. In the improved gas lamp a

regulating device provides for an adjustment of both air and gas. When this regulator is moved forward, the gas and air supplies that enter the mixing chamber are both reduced; when it is turned in the opposite direction, the supply of air and gas is increased. When one uses the gas lamp and gas mantle, efficiency depends upon the accurate adjustment of air and gas. After these are adjusted no further attention should be necessary so long as the source of supply remains constant and without varying pressure.

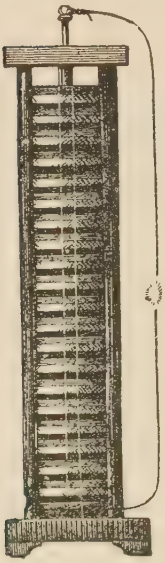


Fig. 161.—The Voltaic Pile.

For his gas mantle and modified form of Bunsen burner Welsbach deserves much credit. With the clay tip burners, 1000 candle-hours of light cost 90 cents, while with the gas mantle 1000 candle-hours cost only seven cents. The gas lamp with its mantle was immediately adopted as a means for lighting the homes, the factories, and the streets of cities. The use of the gas lamp intensified commerce and industry, and greatly advanced social progress.

Electric Lighting; the Electric Arc Lamp.—Nearly all the boys and girls of today have played with or have had something to do with batteries, toy motors, and toy dynamos. They are also quite familiar with the fact that wires of copper and iron will carry currents of electricity when properly connected with any source that is capable of supplying electrical

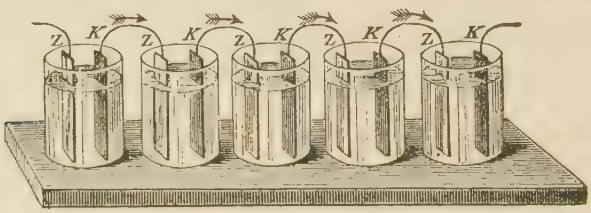


Fig. 162.—Volta's crown of cups or battery.

energy. They have push "buttons" set in the walls for the purpose of "turning on" and "turning off" the lights. They are acquainted with electrical appliances used in and about the automobile. Indeed the use of electricity has become so wide-

spread and far reaching that it is difficult for us to imagine how man ever got along without its aid.

A little over a century ago Volta invented his peculiar form of electric battery—*the voltaic pile*. He took a piece of zinc with a wire fastened to it. On the zinc he placed a piece of cloth saturated with acid or salt. Over the cloth he placed a piece of copper. On the copper he placed a piece of zinc, then a saturated cloth followed by another strip of copper. He continued this building up process with zinc, saturated cloth, and copper, until he had a considerable pile. To the last piece of copper he attached another wire. When the ends of the two wires were touched together and then separated, Volta observed a brilliant flash of light.

Later he used strips of copper and zinc, and in place of the saturated cloth he used glasses containing solutions of acid. Into each glass he placed a strip of copper and a strip of zinc. The zinc of one glass was fastened to the copper in the next; a copper wire was attached to the copper of the first glass, and similar wire to the zinc in the last glass. When the ends of these wires were touched and separated, a much better spark was obtained. To this arrangement was given the name *Voltaic battery*. This was considered to be a great discovery. Volta was called to Paris by Bonaparte to receive honors and a medal in commemoration of the event.

Sometime afterwards Sir Humphrey Davy of England constructed a voltaic battery on a much greater scale. He fastened small sticks of charcoal to the ends of each of the wires. When the ends of the charcoal were touched together, they became heated and glowed brilliantly. When the sticks were slightly separated, the current continued to flow, producing an arching flame of dazzling whiteness between the ends of the charcoal sticks. The light given off was described by Davy as possessing intense whiteness. Davy gave the name *electric arc* to this source of light. Great predictions concerning the possible uses of the electric arc were made. But the possibility of using such a source of light for general purposes was out of the question, because at this time there were no means of producing a constant supply of electric energy.

Hence Davy's arc light was compelled to wait until someone contrived a method whereby electric energy could be cheaply and continuously generated.

In 1831 Michael Faraday, Davy's pupil, discovered that when a coil of wire was rotated between the poles of a horseshoe magnet, Fig. 163, a current of electricity coursed through the wires of the coil. This gave the world a new idea—the possibility of making an electric machine for generating electric currents. About forty years later Gramme, Siemens, Brush, and others developed dynamos that put the principle discovered by Faraday upon a working basis. Brush, an American, was

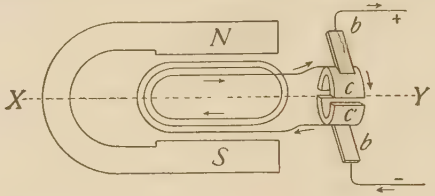


Fig. 163.—When the coil of wire is rotated between the poles of a magnet, an electric current is produced in the wire, which flows through an external wire by means of brushes, *bb*, that bear on the commutator, *cc*. (*From Tower, Smith, Turton and Cope's Physics.*)

practically the first inventor to make dynamos of a large capacity. In the latter part of the nineteenth century he exhibited at Paris a Brush dynamo; it weighed two tons and had a working power of thirty horses. When exhibited this machine was supplying forty arc lamps, each of which gave forth a light equal in radiance to that of 1000 candles. From this time on the arc light came into general use. Special forms of arc lamps were invented in which the carbons automatically adjusted themselves to give the greatest amount of light. Everywhere cities installed electric light plants and lighted their streets continuously throughout the night. Vandalism and roguery, which were so common in cities, grew less, and thus comfort and safety became more secure.

The Filament Lamp.—While the electric arc is very useful in every way for illuminating streets, railway stations, mills, manufacturing plants, harbors, parks, public buildings, and warehouses, it was not suitable for home lighting. There was a desire for a more simple and convenient means of using elec-

tricity as a lighting agent. Toward the end of 1879 Edison in America and Swan in England, independent of each other, produced a filament lamp. In each case the inventors enclosed a fine filament of carbon in a glass globe from which the air was exhausted. The ends of the carbon filament were attached to platinum wires which passed out through the walls of the glass globe. Platinum was then used because it was the only known metallic conductor that would seal with the cooling glass without breaking it. Other metals having rates of expansion and contraction differing from that of glass could not be used. The ends of the platinum wires terminated in different metallic portions at the base of the lamp. When the lamp was screwed into its place, it was automatically connected with two electric supply wires. When the current was turned on, it was conducted to the carbon filament by one of the platinum wires and away by the other. As the current passes through the carbon filament, it becomes heated and finally incandescent—that is, giving off heat and light.

While the carbon filament did not give off a great deal of light (from 16 to 32 candles, depending upon the size), the light-giving filament enclosed in its glass globe was the safest and most convenient form of lamp that had yet come into use. The carbon filament lamp revolutionized light systems of every kind. Electric companies grew up in cities, towns, and villages. The prosperity and progress of a given locality was read from the number of electric wires strung through its streets.

The carbon filament lamp continued in almost uninterrupted use until 1907. There had been many attempts to find new materials of better light-giving qualities. Every conceivable substance was worked into filaments and tried out in the hope of obtaining a filament that would give greater amounts of light and use less current. Finally tungsten, a metallic element which had proved to be a very stubborn and unyielding substance, was properly prepared and shaped into filaments. Using the same amount of current as the carbon filament, the first tungsten lights gave twice as much light. In 1914 the tungsten lamp was again improved; its filament was wound into a spiral form and the globe was partially filled with an inactive

gas—nitrogen. This improved form gave a pure white light of an intensity many times that of the carbon filament. The nitrogen-tungsten lamp has proved itself so serviceable that it is replacing all other forms of artificial light—even to the extent of replacing the electric arc on streets and in other places.

Independence and Social Organization.—So long as firebrands, oil-lamps, and candles were used for lighting purposes, the family gathered its own raw materials and prepared the necessary light-giving instruments of the home. So far as the lighting of the home was concerned, the family was independent of every other family. If the home went in darkness, if the quality of the oil was poor, or if the candle burned badly, the fault was due to methods and materials used in the immediate home. At this time the home was not only preparing oil and manufacturing candles, but it was preparing food and clothing materials, manufacturing implements, and many other materials and articles necessary to the welfare of the home. The home was a workshop where labors of every kind were performed. It is hardly necessary to say that where people must perform all sorts of labors, few, if any, of them will become skilled in the performance of the several duties. Consequently some labors are quite certain to be done poorly.

Finally enterprising persons who found that they could execute certain labors well, directed themselves to the performance of this particular kind of work. Perhaps they could refine oils and waxes, and manufacture them into candles better than any one else in the community. Recognizing this, they started a candle factory. The people of the neighborhood bought the good candles made by the skilled candle makers. After a while the community came to depend upon the candle factory, and so the people became less and less skilled in the art of candle making. Indeed, they became so uninformed and unskilled that they could no longer prepare the oils and manufacture them into candles. In other words the family lost its independence. Its members had become dependent upon the candle factory for a means of lighting their home.

When the kerosene lamp came into use, there was hardly a portion of it that could be produced in the home. Glass

factories were necessary to manufacture the chimney. Iron and copper had to be mined, smelted, and manufactured into a burner and other portions of the lamp. A wick must be properly woven of suitable materials. Oil must be discovered, refined, and purified. Trains and boats were required to carry the oils to market where merchants kept it for sale. If any one of these organized groups of people failed, the kerosene lamp was of no use as a lighting instrument. Hence the person who used a kerosene lamp was dependent upon the labors of many thousands of other persons.

The passing of the kerosene lamp and the adoption of the gas and electric systems of lighting are only due to a greater and closer organization of the people who are willing to become more and more dependent upon each other's labors. The maker of electric lamps in the state of New York produces lamps for the people of the wheat regions, for the people of cattle grazing regions, for the cotton growers of the south, and for the householder and shopkeeper wherever located. In turn these distant people make it possible for the lamp maker to have bread and meat on his table and materials for his clothes. Such an organization of the human multitudes is only possible when every individual renders useful service to the human multitude that has so organized itself. A nation has been defined as a social unit—that is, a group of people living in well defined borders, supporting a common government, and working towards a common end. Man's willingness to coöperate with his fellow man comes from his desire to escape the bondage of nature, to work out a solution of the hidden mysteries of nature, and to direct the forces and materials of nature to his service.

Projects

1. To demonstrate the relationship of the earth, moon, and sun during eclipses.

Suggestion.—Make and use wall charts.

2. To make a study of the conditions necessary to the production of silhouettes and shadows.

Suggestion.—Demonstrate. Show conditions necessary for both umbra and penumbra.

3. To make a study of star clusters in order to identify some of the major constellations for the purpose of determining directions at night.

Suggestion.—Report to the class by means of wall charts.

4. To make a study of mythological characterization of the major constellations.

Suggestion.—On a large chart indicate the stars of the major constellations. Draw dotted lines between the stars in order to show the form of the group so characterized.

Reference.—A Study of the Sky by Howe.

5. To make a study of the solar system in order to know the earth's relationship to it.

Suggestion.—Make and use a wall chart.

FIG. 164.—Illustrating danger from shock because of contact with an electrical fixture having an exposed metal frame which is not grounded. Note insulating ring at *C* behind the fixture. The path of the possible current from *A* to *B* is roughly indicated by the broken lines across the body. This condition sometimes happens when a fixture wire with broken insulation comes in contact with the exposed metal part of an ungrounded fixture. (Installation rules eliminating this possible hazard have been formulated by the Bureau of Standards.) (*U. S. Bureau of Standards, Circular No.* 75.)

6. To make a study of timekeepers, chronometers, and various means employed for telling time.

Suggestion.—Demonstrate by means of drawings, models, and pictures. Lantern slides of tower clocks, historical time pieces, and sun dials may be found in city libraries.

7. To make a study of the conditions that give rise to Standard Time.

Suggestion.—Use a map of the United States and point out the time belts during your report.

8. To collect and place on exhibition oil lamps, candle sticks, and other historical lighting instruments.

Suggestion.—Display the collection in the school show cases. Properly label and give bits of information with each article.

9. To make a study of a gas plant and to build a working model for purposes of demonstrating the operating principles of the type studied.

10. To make a study of an electric light plant and to build a working model out of toy machines for the purpose of demonstrating the working principles of such a system.

Suggestion.—Arrange and fasten all parts of the working model to a single board so that it may be quickly and conveniently demonstrated. Show transformations of mechanical to electrical energy; and electrical energy to heat and light forms of energy.

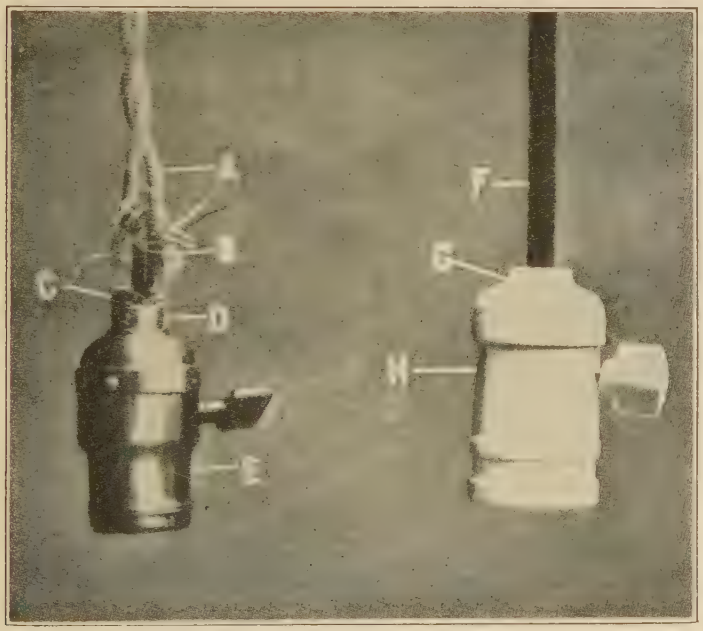


FIG. 165.—Examples of bad and good methods used in portable lighting (*U. S. Bureau of Standards, Circular No.* 75). Note the broken bushing at *C* in the brass socket *E*, exposing the nonreinforced lamp cord *A*, abraded at *B* by the cutting edges of the brass threads in the neck of the socket *D*, injuring the insulation and exposing the live wire in contact with the metal socket. A person using the socket may receive a shock. A nonabsorptive insulating socket, such as the porcelain one *H*, which is shown wired with reinforced lamp cord *F*, will insure adequate protection to the cord, by the rounded neck *G*, and to the user.

11. To make a study of the history and importance of the gas mantle.

12. To make a study of the lives of Sir Humphry Davy and Michael Faraday.

Suggestion.—Report in the form of a biographical sketch in which the lives and works of the two men are compared.

13. To read Michael Faraday's *Chemical History of a Candle.*

Suggestion.—Make a book report.

14. To make a study of an acetylene lamp and by means of a bicycle acetylene lamp to demonstrate the uses of acetylene in the production of artificial light.

Suggestion.—Emphasize the dangers that arise when acetylene is used improperly. As an aid while demonstrating make a cross-section drawing of a bicycle lamp and exhibit it as a wall chart.

15. To draw up a set of safety first rules concerning the use of electricity in the home.

Suggestion.—See Fig. 164 and Fig. 165.

CHAPTER XVII

ILLUMINATING OUR HOME

Object.—To make a study of the conditions that are necessary for the proper illumination of the home.

How Shall We Use Our Lights?—Less than a century ago mankind was struggling under the flickering flames of oil-lamps and candles. During the past fifty years man has been transported from a world of days and nights to a world of continuous day. Fifty years ago the problem was one of getting a light to use. Today the problem is how we can best use the light which we have. A few decades ago eye strain and eye fatigue arose from under-lighting effects. Today these ills arise from over-lighting, or the improper use of strong lights, or both.

Today homes are flooded with light, yet they are poorly illuminated. Illumination refers to the surface of the object which one is observing. If the object presents itself correctly to the vision, it is properly illuminated. If this is true of the several objects about the room, the room is properly illuminated. Illumination is not the source of light; it is the result from the presence of the source of light.

In bygone days the candle was set in the middle of the dining table, and no noticeably bad effects resulted from its presence there. The people seated about the table could look to the opposite side or at the candle and suffer no particular discomfort from the presence of the candle light. Today we often find electric and gas lamps of great brilliance hanging above the center of the dining table. Very often these lights are placed at a height that allows the rays of light to shine directly into the eye. Furthermore, such light is strongly reflected by the dishes and tablecloth. Such conditions besiege the eye with a flood of light that is discomforting. While the table and its several articles are strongly lighted, the whole effect is one of

very poor illumination. Brilliant lights are not forbidden, but it is necessary that they be kept out of the way of the eye.

Just as the campfire in its day brought much cheering comfort to those assembled, so should modern lighting systems be powerful influences in making houses into homes. A home that is properly illuminated is expressive of comfort and restfulness. In order to appreciate fully the importance of correct lighting effects in the home or shop, it is quite necessary that we know something about light, its properties in a general way, the means of transmitting it, and the methods used for distributing it for illuminating purposes.

LIGHT TRAVELS IN STRAIGHT LINES (HOME PREPARATION)

Object.—To determine whether or not light travels in straight lines.

MATERIALS.—Three cardboard squares 6″ × 6″. Six blocks or books. Candle.

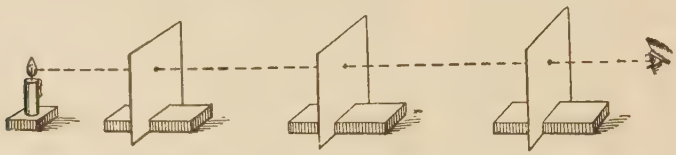


FIG. 166.—Does light travel in straight lines?

PROCEDURE AND OBSERVATION.—Arrange the materials as shown in Fig. 166 and make your observations. What is your conclusion?

SHADOWS (HOME PREPARATION)

Object.—To make a study of the conditions that give rise to shadows.

MATERIALS.—Two candles. Cardboard square, 2″ × 2″. Cardboard 6″ × 6″. Screen or nearby wall.

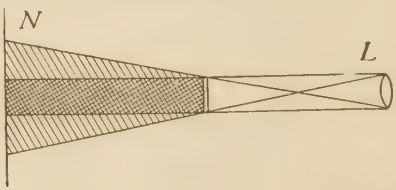


FIG. 167.—A condition that gives rise to umbra and penumbra shadows (*From Tower, Smith, Turton, and Cope's Physics.*)

PROCEDURE AND OBSERVATIONS.—1. Place the cardboard (2″ × 2″) between the candle (*L*) and the screen (*N*) as shown in Fig. 167. Adjust the card so as to show two shadows—a dark shadow surrounded by a gray

one. The dark shadow is known as the *umbra;* the gray, the *penumbra.* Adjust the screen so as to give but one shadow—the umbra, Fig. 168.

2. Repeat the experiment with the 6″ × 6″ card.

3. Place two candles side by side and repeat the experiment with the small card and then with the large card.

4. Separate the candles two or three inches and repeat.

Summarize the conditions that give:

(*a*) the best umbra,
(*b*) the best penumbra,
(*c*) no umbra, and
(*d*) no penumbra.

5. Using one light in the room stand so as to observe your own shadow. Is there an umbra and a penumbra? Observe the shadows cast by the furniture and other articles in the room. Turn on a second light located

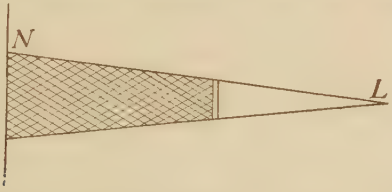


FIG. 168.—A condition that gives one shadow—the umbra. (*From Tower, Smith, Turton and Cope's Physics.*)

at least a few feet from the first. Again observe the shadow effects. As you advance toward a wall, do you observe two penumbras merging into one and possibly into an umbra surrounded by a penumbra?

6. Should a room be so lighted as to show well defined shadows or soft shadows? Do lights and shadows together aid us to see things, or is it better to have a room so lighted as to have no shadows?

REFLECTED LIGHT (HOME PREPARATION)

Object.—To observe and study two sets of conditions, those favorable and those unfavorable to the reflection of light.

APPARATUS.—Small mirror or a piece of mirror glass. Ruler.

MATERIALS.—Squares of blotting paper, white and dark. Squares of white paper having surfaces that are glossy, dull, and rough. Dark papers of various surfaces. Three pins.

PROCEDURE AND OBSERVATION.—1. Lay a piece of writing paper on the table and near the edge of the table. Near the edge of the paper set the piece of mirror in an upright position as shown in Fig. 169. At about six inches before the mirror set a pin (*F*). Holding your eye on a level with the top of the table, locate the image of pin (*F*) in the mirror. The imaginary line running from your eye to the image in the mirror is called the line of vision.

Set two pins on the line of vision. The two pins and the image should be in line as indicated in the figure by *G*, *B*, and *f*. Pin *B* should be placed as near the mirror as it can be placed without disturbing the mirror. Draw a straight line, *AC*, along the face of the mirror. Using the ruler draw a line, *BG*, which passes through the pins *B* and *G*. Connect *B* and *F* with line *BF*.

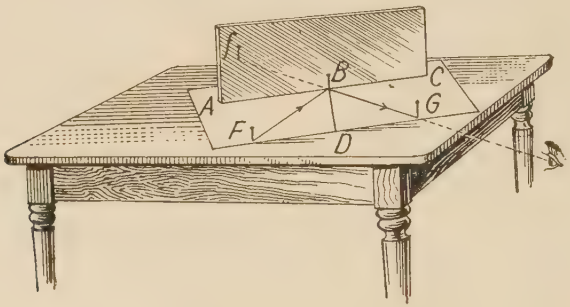


FIG. 169.—Line *FB* is the path of the incident ray. Line *BG* is the path of the reflected ray. Line *BD* is drawn perpendicular to the surface of the mirror.

Remove the pins *B* and *G* and again level the eye and sight along the line *BG*. Does the line appear to go directly to the image *f*? The line *FB* represents the path of a ray of light that strikes the mirror at *B*. The mirror does not allow the light to pass, but reflects it in the direction of the line *BG*.

The light which falls upon the surface of a body is called the *incident light*. That which is thrown off is called the *reflected light*. In your

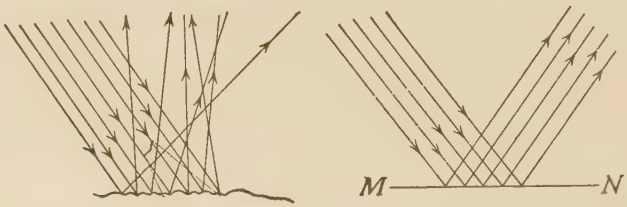


FIG. 170.—The reflection of light from smooth and rough surfaces. The reflection from rough surfaces produces diffused light. The reflection from smooth surfaces gives high lights and causes glare. (*From Tower, Smith, Turton, and Cope's Physics.*)

drawing let the line *FB* represent the *incident ray;* and line *BG*, the *reflected ray*.

At point *B* erect a perpendicular *BD* to the mirror line *AC*. Observe the two angles *FBD* and *GBD*. If the work was correctly done, the two angles are equal. Angle *FBD* is the *angle of incidence*. The angle *GBD* is the *angle of reflection*. Study Fig. 170. Whenever light is reflected the angle of incidence is equal to the angle of reflection.

2. Place the pieces of white paper on the table. Observe their surfaces and determine which of the pieces reflects the greatest amount of light. Arrange the pieces of paper in order of their reflecting qualities. Which of the papers would be best to use as a wall paper for side walls? Would the paper which you have chosen be the most restful to the eyes? Which of the papers would serve the best as a wall paper for ceilings? Do ceilings of rooms serve as reflectors for distributing the light about rooms and thus aid in illuminating the room?

3. Observe Fig. 171. When a shaft of light strikes a fairly smooth surface, semi-mat, the shaft of light is reflected as several lesser shafts. When the shaft strikes a rough mat surface, the shaft is reflected as lesser shafts in all directions throughout the room. In which case would less light be reflected into the eye? Which would produce the best conditions for comfort: a smooth surface, a semi-mat surface, or a rough-

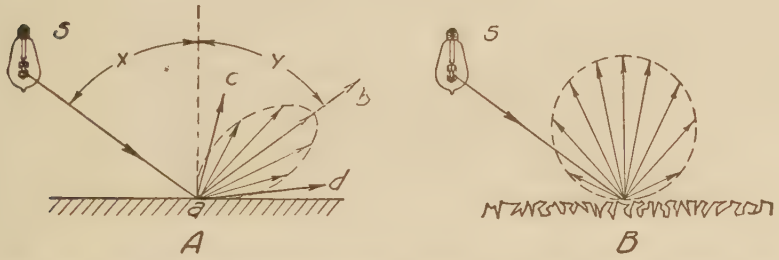


FIG. 171.—*A*, Reflection from semi-mat surface; *B*, reflection from rough mat surface. (*Courtesy of General Electric Co.*)

mat surface, on side walls? Which would be the best for ceilings in order that the ceilings may aid in illuminating the room to the best advantage?

4. Which of the books and magazines are least tiring and easiest to read, those whose pages are highly polished, medium polished, dull coated, or rough? Which of the surfaces are used in the better books and magazines?

5. Repeat (2) using papers that have dark colored surfaces. Are dark colored papers ever used for ceilings? Explain. For side walls? Explain.

6. Do dull black surfaces reflect or absorb most of the light? Do polished black surfaces reflect or absorb light? Which of the two kinds of surfaces reflects the more light? Which absorbs the more light? When other conditions are the same, why is it darker on a summer night than on a winter night when the ground is snow covered? If two rooms are of the same size, lighted by similar lamps similarly placed, and all other conditions are the same except that one room is papered green and the other white, which appears to be the more brightly illuminated? Explain.

7. Summarize the use of surfaces for illuminating purposes from the standpoint of surface and color.

LIGHT AND COLOR

Object.—To discover the relation of light to color.

APPARATUS.—Prism.

MATERIALS.—Color card or strips of colored papers. Sheet of white paper.

PROCEDURE AND OBSERVATIONS.—1. Darken a room which has windows exposed to the sun. Raise the shade of one of the windows just enough to allow some sun light to enter. Place the prism in the sunlight, and adjust it so as to produce the best spectrum on an opposite wall. Fix the prism in place and study the colors that make up the spectrum. There are seven individual colors—spectrum colors. Discover each color and memorize each in the order of appearance. If white light enters the prism, how is it possible for seven shafts of colored light to emerge? There is but one conclusion—the entering white ray is, at least, made up of seven colored rays.

2. Hold a piece of white paper in each color. Does the white paper reflect the primary color in each case; that is, does the white paper appear red in the red portion of the spectrum? Does a piece of white paper reflect blue when held in the blue portion? Repeat the experiment with a white envelope that carries a red postage stamp. Where does the stamp appear as a pure red stamp? What color is the stamp in the blue portion?

Red surfaces are red because they can reflect only red. Consequently when a white light falls on a red surface, it reflects only the red portion of the light and absorbs the other six colors. When red light falls on a red surface, the red surface reflects the red and hence the surface appears intensely red. When a blue light falls on a red surface there is nothing to reflect; consequently the red surface appears black.

What happens when a white light falls on a blue surface? When a blue light falls on a blue surface? If you are unable to answer the above questions, actually try them out with the prism and from observations discover the answer and reason.

Black surfaces are black because they absorb all the colors.

What effect would red lights have on the walls of a room decorated in white? In blue?

Why is white light the best light for examining the color of materials? For illuminating the home?

Examine the color of various fabrics by the light of a carbon filament lamp; by a tungsten; other sources. Repeat in the open light or direct sunlight. In which case did you see the true color of the fabric? Which of the artificial lights is the most dependable for judging colors?

Why Things are Visible.—Any source of light—a candle flame, an incandescent filament, and the like—radiates light

in all directions. In fact every point of the flame or incandescent body gives off light in every direction. When our vision is directed toward the source of light, we see the source itself by means of the radiated light that travels from the source to the eye (as shown at *M* in Fig. 172). However, when our vision is directed to an object that receives light from any source, we see the object by the light that it reflects to our eye (as shown at *N* in Fig. 172). Hence those bodies that radiate light present themselves by means of radiated light, while those that are incapable of radiating light present themselves to our vision by means of reflected light.

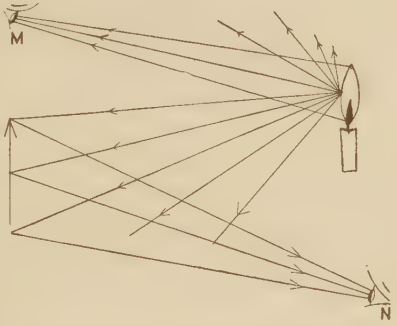


FIG. 172.—*M*, Incandescent bodies radiate light to the eye; *N*, cold bodies are seen only by reflected light.

When we step out of doors into the sunlight, we are able to observe a multitude of different objects which reflect the sunlight that they receive. Some of the objects seem to reflect greater amounts of light. The cement walk that runs across the lawn throws back such great quantities of light that we are in the habit of directing our eyes away from the glare and toward the green grass of the lawns. This state of affairs is due to the fact that surfaces are never perfect reflectors. For, when light falls upon a surface, two things always occur—part of the light is absorbed and part is reflected. Tree trunks and black soils absorb far greater amounts of light than they reflect back into space. The absorbed light is changed to heat and passes farther into the absorbing body. From these considerations surfaces are classified as good reflectors and poor absorbers, or as poor reflectors and good absorbers.

Transparent and Opaque Bodies.—A third class of bodies—glass, diamonds, thin crystals, and water—allow great amounts of light to enter, pass through, and go out again into space. Such bodies are transparent to light and are often referred to as *transparent bodies*. However, no ray ever passes through

a transparent body without suffering losses. As the ray seeks to enter a glass plate, part is reflected, a second part is absorbed while passing through the layers of glass, and the portion that remains escapes into the space beyond. Clear and uncolored glass is one of the most transparent substances which we have, and for this reason it is used as window glass, as lamp chimneys, and as lamp globes.

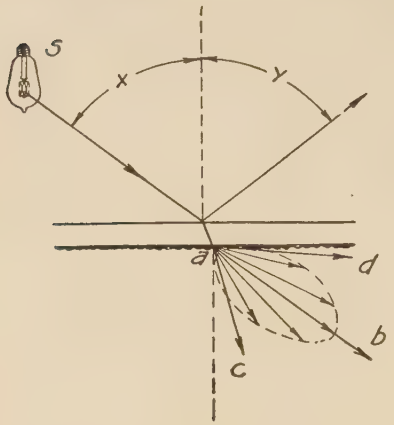


FIG. 173.—Reflection and transmission by etched glass. (*Courtesy of General Electric Co.*)

When each of the two surfaces of a piece of glass are smooth and polished, we can see objects on the other side. For example, when we look through ordinary window glass, we see things out of doors. However, if one of the surfaces of a window pane is frosted or etched so that it is rough, the light comes through to us, but we are unable to see any objects that

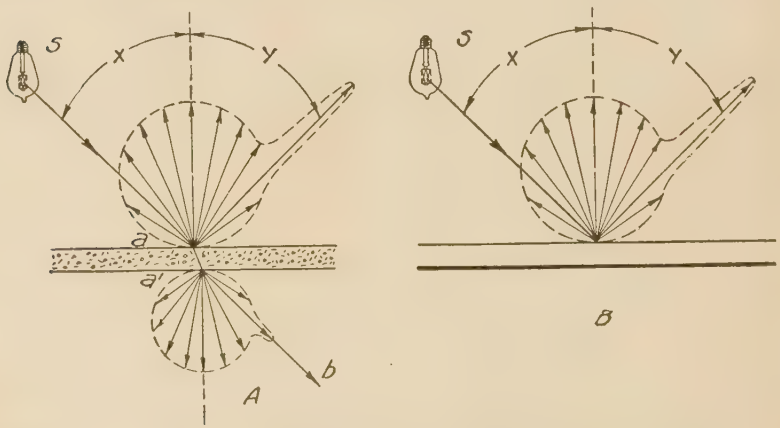


FIG. 174.—*A*, Reflection and transmission of opal glass; *B*, reflection from porcelain-enameled steel. (*Courtesy of General Electric Co.*)

are located on the opposite side. This is because to the ray is greatly dispersed while travelling through the frosted surface. See Fig. 173. Those substances that allow the light to pass

through, and at the same time shut off the possibility of seeing through them are called *translucent bodies*. Glass panes used in hall doors and office windows are usually roughened, etched, or frosted, and thus light is admitted without the loss of privacy. Glass globes and chimneys are often frosted for purposes of obscuring strong sources of light while allowing illumination to take place. Thin porcelain ware and opal glass are used for manufacturing lamp-shades and lamp reflectors, for the reason that their surfaces disperse both the reflected portion and the transmitted portions of the light shaft. See Fig. (*A*) 174. Those materials that allow no light to pass through them are called *opaque bodies*. When their surfaces are etched or flaked with enamel substances, they disperse the reflected light in every direction as shown in Fig. (*B*) 174.

Each of the materials described above is used in connection with the illumination of the modern home. The use of strong lights require that we make the proper use of these materials in order to obtain the correct illuminating effects.

Light and Color.—When a ray of sunlight is made to pass through a prism, the ray is so dispersed as to give seven prominent colors—red, orange, yellow, green, blue, indigo, and violet. These seven colors are commonly known as the *spectrum colors*. The fact that a white shaft of sunlight is made up of a blending of all seven colored rays seems marvelous and to some people impossible. Nevertheless all the rays of the sun are composed of these seven spectrum colors, and it is due to their presence in every sunbeam that the beauties in nature exist as we see them.

Spectrum primary colors are: Blue, green, red. The primary colors in artists' paints are: Blue, yellow, red.

A yellow cannot be made by mixing pigments, but the artist or painter can make:

Green by mixing blue and yellow
Orange by mixing yellow and red
Violet by mixing blue and red
Indigo by mixing blue with a little violet.

When a white surface is held in a white shaft of light, it reflects white light and appears white. However, when the

white surface is exposed to a red light, the white surface reflects red light and thus appears red. Orange light causes a white surface to appear orange in color, and the remaining colors act similarly. This characteristic is a property of all pure white surfaces. When a red surface is held in a shaft of white light, it appears red for the reason that red is the only color in the sunbeam that a red surface is able to reflect; the other six colors are all absorbed. When a red shaft of light is directed upon a red surface, the surface appears intensely red, for the reason that the red light is reflected. However, if a blue, or green, or violet shaft of light is thrown upon a red surface, it appears

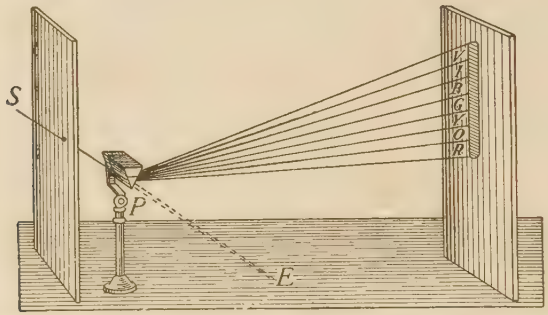


FIG. 175.—Formation of the spectrum of a prism. (*From Tower, Smith, Turton, and Cope's Physics.*)

black for the reason that these colors are completely absorbed. Hence a red surface appears red on account of its ability to absorb all the colors excepting red, which it reflects. In the same manner a green surface is one which absorbs all colors excepting green, which it reflects. A black surface is one that absorbs all the colors and consequently appears black in the presence of any light, while a white object reflects all the colors and therefore appears as white. Hence the color of any object is due to the light which it reflects.

The Intensity of Light.—Fifty years ago, when other light sources began to take the place of the candle, it was natural for the people to speak of the flame of a lamp as being equal to that of so many candle flames. The flames of ordinary kerosene lamps were often rated as being equal to eight candles, while the flames of larger kerosene lamps were rated anywhere from

ten up to twenty candle flames. At first there was no regular way of telling just how many candle flames there were in any of the new flames. The people simply made comparison by setting the two flames beside each other in the line of vision, and the strength or intensity of a flame was simply a matter of personal judgment. This idea of comparing the brilliancy of a source of light with that of the candle is still in use, but very accurate methods for comparing two sources of light are used in the place of the "guessing" method of earlier days.

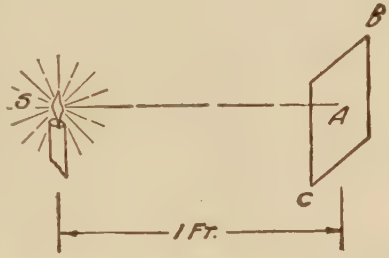


Fig. 176.—The illumination at *A* is 1 foot-candle. (*Courtesy of General Electric Co.*)

As was stated in the introduction to this chapter, light is a cause, and illumination is the effect or result. The light itself is measured in candles, but to measure the illumination on a newspaper, a picture, or a desk we use a unit called a *foot-candle*. A foot-candle represents the degree or intensity of illumination produced by a candle on one square foot of surface which is one

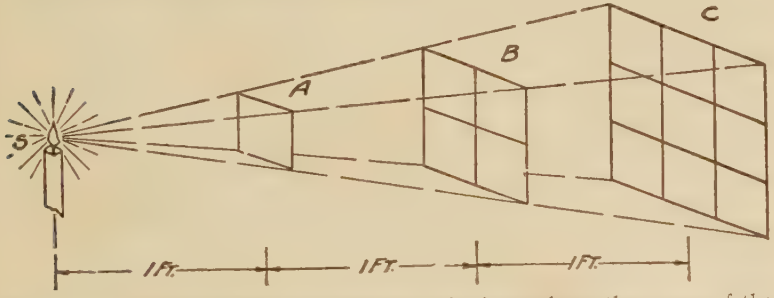


Fig. 177.—The illumination on a surface varies inversely as the square of the distance from the source to the surface. (*Courtesy of General Electric Co.*)

foot away from the candle. In Fig. 176 we have a candle one foot away from a piece of paper whose surface is one square foot. The lighting or illuminating effect on the paper is called a foot-candle. If two candles were used instead of one (in Fig. 176) the illuminating effects would be two foot-candles. If ten candles were used, the square foot of surface would receive ten foot-candles.

In the above discussion the paper was held exactly one foot away from the candle. What would happen if the square of paper were moved away from the light? Figure 177 indicates exactly what would happen if the screen were moved a distance of two feet or three feet away. As the rays of light travel away from the candle, they become more and more widely separated. At a distance of 2 feet a foot-candle is spread over 2×2 feet or 4 square feet of surface, and therefore one square foot receives only $\frac{1}{4}$ of a candle-foot of illumination. At a distance of 3 feet the light is spread over 3×3 feet or 9 square feet of surface, and therefore one square foot receives only $\frac{1}{9}$ of a foot-candle. At a distance of 5 feet we would have $\frac{1}{5 \times 5}$ or $\frac{1}{25}$ of a foot-candle per square foot. From this we conclude that the intensity of illumination falls off not in proportion to the distance, but in proportion to the square of the distance. This relation is commonly known as the law of inverse squares.

Problem.—What must be the candle power of a lamp to be able to give 1 foot-candle per square foot on a wall located 10 feet away?

Solution.—At a distance of 10 feet 1 candle would give $\frac{1}{10 \times 10}$ or $\frac{1}{100}$ foot-candles per square foot.

Therefore, 100 candles would give $100 \times \frac{1}{100}$ or 1 foot-candle per square foot. Therefore, a lamp of 100 candle power is required.

How Count Rumford Measured the Candle Power of His Lamp.—Count Rumford (Benjamin Thompson), an American by birth, devised a very simple method for determining the candle power of lamps. A lighted lamp and a candle were so arranged as to cast shadows of a rod upon a paper screen, as shown in Fig. 178. The candle was moved forth and back until the two shadows stood near each other and were of the same degree of darkness. When this happened he knew that the screen received equal amounts of light from the candle and the lamp. He measured the distances between the lamp and the screen, and the candle and the screen. Then he applied the principle dis-

cussed in the preceding pages—that is, he compared the square of the lamp's distance from the screen with the square of the candle's distance from the screen. The answer thus obtained gave the candle power of the lamp.

$$\frac{\text{Distance LS} \times \text{distance LS}}{\text{distance CS} \times \text{distance CS}} = \text{candle power of lamp.}$$

FIG. 178.—The method used by Count Rumford for measuring the candle power of his lamp.

How Much Light Shall We Have in Our Rooms?—In order to answer the question some important factors must be taken into consideration. The surface of the walls, the ceiling, the character of the furniture and other decorations, and the purpose of the room, all play important parts in determining the amounts and arrangement of lights. A room whose walls and ceiling are covered with white wall paper or other "white finish" will require less light than a similar room having a "dark finish." The walls of the room finished in white will reflect 80% of the light back into the room. One finished in light gray will reflect

TABLE OF COLORS USED FOR FINISHING WALLS AND CEILINGS WITH THEIR REFLECTION FACTORS

COLOR	PER CENT	COLOR	PER CENT
Ivory white	76	Cocoanut brown	22
Caen stone	72	Cardinal red	27
Ivory	72	Forest green	21
Ivory tan	58	Satingreen	67
Primrose	67	Bright sage green	43
Lichen gray	70	Olive green	14
Pearl gray	70	Pale azure and white	53
Silver gray	50	Sky blue	31
Buff stone	44	Shell pink	58
Buff	59	Pink	51
Tan	37		

from 51% to 73% of the light, while one finished in very dark gray will reflect from 18% to 51% depending upon the shade of gray used. While color plays an important part in the reflection of light, the character of the surface also determines the nature of the reflection.

Rough surfaces and semi-mat surfaces diffuse and soften the reflected light, while smooth and glossy surfaces give quite the opposite effect. Walls which reflect less than 50% of the light which strikes them should not produce discomfort, provided, of course, that they are of a mat or semi-mat finish. Walls finished in buff, light green, or gray reflect about the proper proportion of light, and their use is meeting with general favor. Walls finished in a high gloss are not satisfactory from a standpoint of glare. Rooms containing dark furnishings require greater amounts of light than those furnished in the lighter tones.

Since the above factors take such an important part in the illuminating effects of a room, it is quite impossible to give a general rule governing the amount of light which should be provided. However, since most of the lamps, gas and electric, which are sold upon the market are rated in candle power, some facts and principles may be given which aid in determining the correct illumination of any room. Electric filament lamps are usually rated as 16-candle power, 32-candle power, 64-candle power, and higher. Now a 16-candle power lamp illuminates a surface 1 foot distant with an intensity of 16 foot-candles, but, if the wall is 4 feet distant, the intensity is only 1 foot-candle. And so, if a person requires an intensity of 2 foot-candles on the surface of a table which is 4 feet from the light, he will be required to use two 16-candle power or one 32-candle power lamp. In reading rooms the general illumination should be from 2 to 5 foot-candles; in public halls, auditoriums, and churches, from 2 to 5 foot-candles; and for homes, the average is from 2 to 3 foot-candles. The illumination for all kinds of desk work, such as that required of students and book keepers, is from 3 to 5 foot-candles, while drafting and engraving surfaces should receive from 10 to 20 foot-candles.

The Wrong Use of Strong Lights; Glare.—A glance at the sun proves that an extremely bright source of light within the

field of vision is capable of producing great discomfort. Light sources of far less brilliancy than the sun, such, for example, as the filament of an electric lamp or the incandescent mantle of a gas lamp, are also quite capable of producing discomfort by

FIG. 179.—Direct glare is the most frequent and serious cause of bad lighting. (*General Electric Co.*)

FIG. 180.—Reflected glare from polished surfaces is particularly annoying, because the eyes are not fitted by nature to receive light from below. (*Courtesy of General Electric Co.*

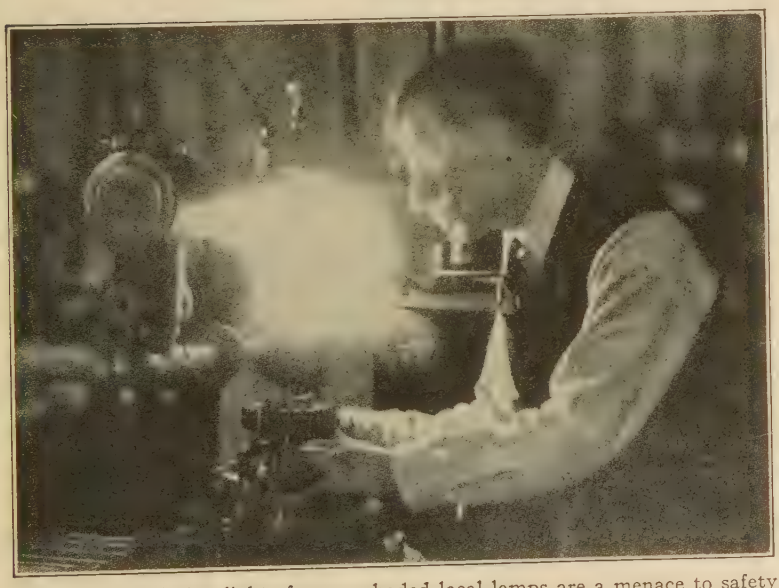


FIG. 181.—Glaring lights from unshaded local lamps are a menace to safety and to vision, and are one of the evils of present day lighting systems that should be eliminated. (*Courtesy of General Electric Co.*)

direct glare. During the day, rooms are generally lighted by admission of natural light by means of windows. Unless the room

is very dark or the landscape is very brilliant, the effect of looking out of the window for a moment will not be unpleasant. But to sit all day facing the window would prove extremely tiring, even if one were sitting at a desk or table and not paying particular attention to the window. The same thing is true of the light of a lamp which is not bright enough to cause an immediate sensation of glare but too bright to be viewed continually.

Another instance of glare arises from strong lights in dark back grounds. This is illustrated by automobile lights as seen at night against a wall of darkness, in which case the glare is so great as to produce a temporary blindness. Yet the same lights in the daytime would hardly be noticeable. And so, when rooms having dark walls and dark furniture are illuminated with strong lights, the effect is quite likely to be one of glare, which would not be noticeable in rooms having decorations and walls in a lighter color. Glare is any brightness within the field of vision of such a character as to cause discomfort, annoyance, interference with vision, or eye fatigue.

Choice of Lighting System.—Three general systems of illumination have come into use. They are classified in accordance with the manner in which the light is distributed:

1. Direct-lighting systems;
2. Indirect-lighting systems;
3. Semi-indirect lighting systems.

Direct-lighting systems make use of lights which send their rays directly to the surfaces to be illuminated. Reflectors and shades of translucent glass and porcelain should be used to improve the distribution of light and to diffuse the direct rays of the lamps. Fixtures of the enclosing type, Fig. 182, are coming into use in direct lighting systems. This arrangement distributes the light in all directions and gives a room a bright and inviting appearance.

Open reflectors placed above or about the lamp throw most of the light downward. The majority of fixtures formerly in use were in this class. In the average home this general class is still used in nearly all the rooms, Fig. 183. While such reflectors distribute the illumination, they often give rise

to glare and disagreeable shadows. In such fixtures it is usually advisable to use bowl-frosted lamps.

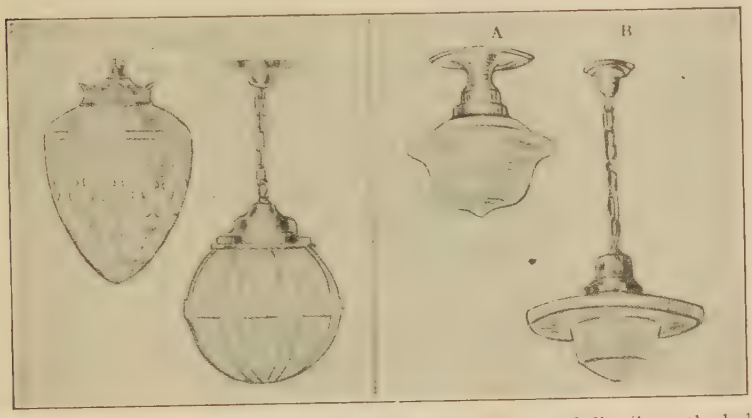


FIG. 182.—Fixtures of the enclosing type used to diffuse and distribute the light in direct lighting systems. (*Courtesy of General Electric Co.*)

FIG. 183.—Open reflectors as they usually appear in the home. (*Courtesy of General Electric Co.*)

Indirect-lighting utilizes the ceiling and walls for reflection and diffusion of the light sent forth by the lamp. In this system the ceiling and the top of the side walls may be con-

sidered as the source of light, and thus any glare from the presence of the light source is avoided and shadows are soft, Fig. 185. This system of lighting is particularly suitable for

FIG. 184.—Fixtures used in indirect lighting systems. (*Courtesy of General Electric Co.*)

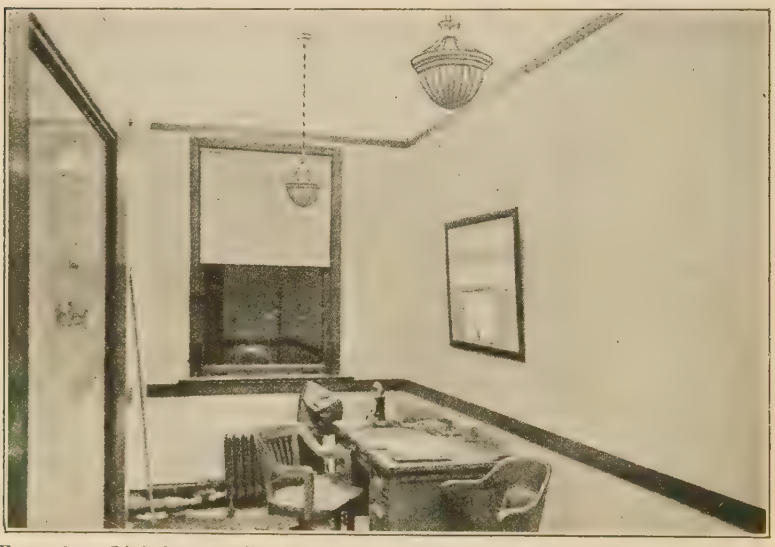


FIG. 185.—Lighting an office by means of indirect units. Illumination approximately 6 foot-candles. (*Courtesy of General Electric Co.*)

an interior in which it is desired to create a subdued and quiet atmosphere. Light-colored ceilings and upperside walls are essential to the efficiency of this arrangement. When dust

and dirt are allowed to collect in the indirect bowl, the illumination is seriously reduced. Figure 184 shows the common type of fixtures that are used in this system of lighting.

Semi-indirect lighting furnishes a means of combining the features of direct and indirect systems. The indirect bowl, instead of reflecting all of the light toward the ceiling, allows portions of diffused light to pass through to surfaces that are directly below. With a correctly designed bowl of dense opal glass, brightness of the lamp and bowl is low enough to avoid eye fatigue, and the amount of light that passes through is not sufficient to cause a glare. Shadows of soft grade, which

FIG. 186.—Fixtures used in semi-indirect lighting systems. (*Courtesy of General Electric Co.*)

are so much desired, are produced. The type of fixture used in semi-indirect systems is very similar in form to that used in indirect-lighting systems, the only difference being that the bowl in one case is a total reflector of the lights that illuminate, while in the semi-direct only a portion of light is reflected onto the ceiling and then downward into the room.

Portable Lamps.—Decorative floor and table lamps are being used more and more extensively, and the many patterns which one finds on the market indicate that practically all of them have been designed from a decorative standpoint rather than for their light-giving qualities. Table and floor lamps must be decorative, but to be useful they should be so designed as to give the best possible lighting effects. The shades must be dense,

because the lamps are low and always in the field of vision. Again, the majority of lamps of this form direct all the light in a downward direction. With a table lamp this usually makes the intensity of illumination on the table top too high for comfort on account of glare. Especially is this true of table lamps when the rest of the room receives no other light.

A table or a floor lamp can be designed as shown in Fig. 187, to be effective (1) by directing downward only enough illumination to give a low intensity on the table top, (2) by lighting the shade sufficiently to bring out the pattern, and (3) by directing the remainder of the light to the ceiling where it is reflected about the room. There are floor lamps upon the market which fill these requirements by a combination of direct and indirect lighting, and they are so provided that the direct or the indirect part of the lamp may be used, and the whole effect is very pleasing.

Fig. 187.—Decorative table lamp designed to utilize the light efficiently. (*Courtesy of General Electric Co.*)

Illuminating Our Home.—In providing for the illumination of a home the aim should be to secure the proper intensity of light, softened shadows, and avoidance of every condition that gives rise to glare. In order to provide sufficient intensity it is not necessary that the largest lamp possible should be used. A lamp large enough to give the amount of illumination necessary for the desired effect is all that is required. For close work, such as reading, writing, or sewing, a high intensity of illumination is necessary, if eye strain and discomfort are to be avoided.

The causes of glare and means of avoiding glare have already been considered. However, it is especially important that glare should not be present in the home, because here the eyes of children, which are particularly sensitive to strong lights and glare, may be permanently injured. In the majority of homes there is still to be found a great deal of glare in the rooms in which people sit and converse; and kitchens and bed rooms in

the average home are so lighted that glare presents itself to the eye from almost every point of view. Reflectors and shades should be used to protect and assist the eye by lessening the conditions of glare wherever and whenever they occur.

When we pass a ray of sunlight through a prism, the ray of light is broken up into its constituent parts and is found to be composed of all the colors from red to violet. Artificial light is also composed of different colors but usually in proportions differing from those in sunlight. Some artificial lights are even lacking in a number of colors. An object appears red, or yellow, or blue, simply because it reflects red, or yellow, or blue rays, and absorbs most of the others that happen to strike it. It is obvious that a red object can not appear red unless red rays are present. Thus it can be seen that the color of an object under most artificial illuminants will appear different from what it will in daylight. Hence the color quality of the light used influences the appearances of the decorations and everything within the home. Nearly all of the artificial illuminants of the present day do not contain as much blue as sunlight, although they are nearer white than the earlier lamps.

No matter how good a lighting system is, it can become very inefficient in a short time if it is not suitably cared for. A scarcely noticeable deposit of dust on reflecting surfaces or globes of lamps may cause as high as a 30% or even 50% loss of light. Dirty reflectors, walls and ceilings darkened by smoke and dust, and blackened lamps left in service as long as they continue to burn are often the cause of insufficient illumination.

Light and Safety; Street Lighting.—Less than one hundred years ago the streets of a city were used at night by an occasional wayfarer or by groups of people who happened forth on account of some unusual occurrence. Today it is very different. In any town or city a street scene at night presents crowds of pedestrians, constant streams of automobiles and other motor vehicles, and numerous street cars, all moving at a speed beyond the imagination of those who lived in the days of candle light.

During the period of the World War, London and many Continental cities were often shrouded in darkness as a matter of precaution against airplane raids. Many writers and news-

paper correspondents have tried to express the depression and gloom of the inhabitants during the periods in which "night darkness" was enforced. During these periods of darkened cities, crime and accidents showed an alarming increase, even though the unpleasantness of travel in dark streets had greatly reduced the amount of street traffic. Never before had the minds of the people been so awakened to the need of light—to the degree of security and personal safety dependent upon its presence.

During the war Chicago turned off the street lights to save coal. The result of the experiment is found in the newspaper headlines:

CHICAGO DARK: BANDITS BUSY
THIRTY-TWO HOLDUPS AND MANY OTHER CRIMES IN TWO DAY PERIOD
ELECTRICITY—THE SILENT POLICEMAN
STREET LIGHTING TURNED OFF TO SAVE COAL, TURNED ON TO SAVE PEOPLE

The demands for good street lighting are the result of the wonderful development of the methods used for lighting the interiors of homes, shops, auditoriums, theaters, and other places of amusement and recreation. The possibility of conducting these activities at night depends upon the degree of safety provided for travelling to and from them at night. As a result progressive cities are installing systems of street lighting which provide for continuous service throughout the night.

In many cities the lighting systems which were installed several years ago are still in use. At the time of installation these systems illuminated the streets sufficiently, but today these systems are inadequate for safety. In 1910, 187,000 passenger and truck automobiles were produced; in 1920, 2,205,000. Today 10,000,000 motor vehicles are coursing the highways and streets of the United States. These great streams of traffic are brought together wherever there is a city through which great numbers of humanity and burdens of

every sort pass every hour of the day and night. Consequently, the street lighting systems that were adequate a few years ago are unable to meet the requirements of today.

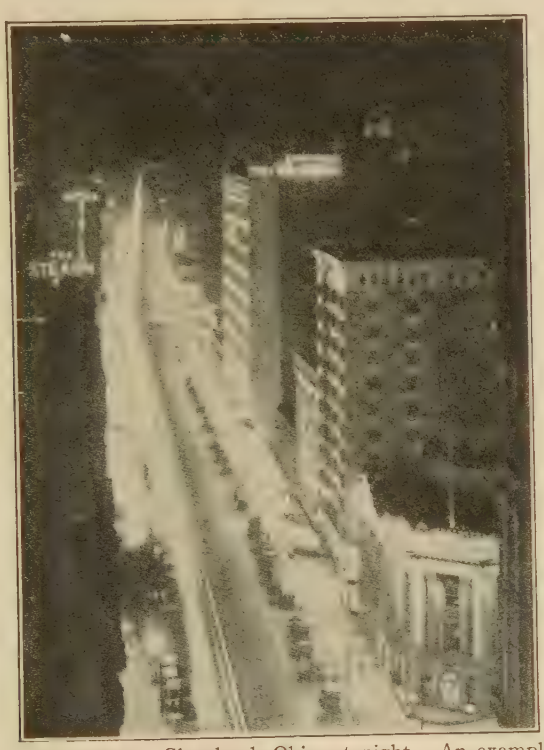


FIG. 188.—Euclid Avenue, Cleveland, Ohio, at night. An example of modern street illumination. (*Courtesy of General Electric Co.*)

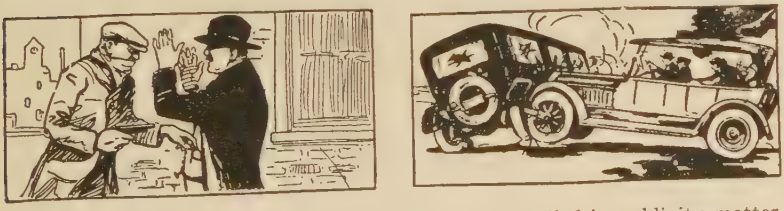


FIG. 189.—Examples from a series of cartoons embodied in publicity matter recently issued in the interest of better street lighting in Chicago. (*Courtesy of General Electric Co.*)

Street lighting is a community problem. The people of an organized community elect their mayor and councilmen who are entrusted with the city's needs. These men usually hire

expert engineers to advise and instruct them how best to solve the problems of a community. Men learned in problems concerned with water and sewage have been hired to solve the city's water and sewage problems. Engineers who have given their time to street building have been called to direct the construction of streets. Indeed a city is very much like one

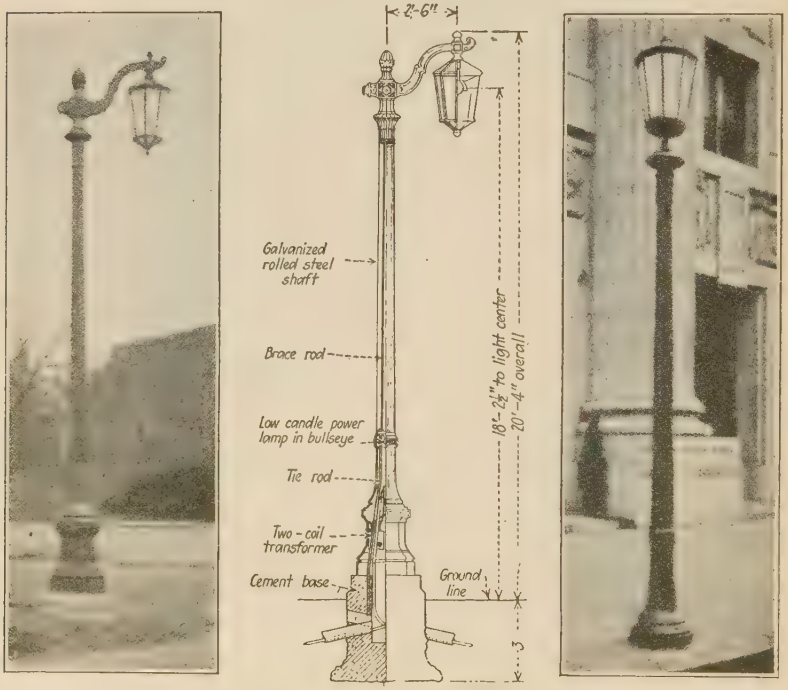


Fig. 190.—Modern types of street lanterns and posts. Street lanterns should be of pleasing appearance both by day and night. (*Courtesy of General Electric Co.*)

great family that has a great number of household duties to look after and to keep in order.

Of course, money is needed for street lighting in the same proportion in which it is needed in the home. The individual who lives in the community shares all the advantages and disadvantages with every other individual of the community group. The growth and development of a city, the comfort and security of a city, in short, every thing that touches upon

the welfare of the city, all depend upon the interest and active coöperation of each and every individual who lives within its confines. Hence the levying and collecting of taxes and the expenditure of the money thus obtained from the community should all be done in the wisest and best ways possible, in order that those who paid the tax money may receive the expected benefits. And those who paid the tax must expect old systems to become inadequate as time passes and habits of living change; they must expect the replacement of old forms of equipment with those more efficient and improved.

While the street lighting problems have not been solved to the same degree that water problems have, much progress has been made. Artistic and serviceable street lamps, uniformly distributed in residential districts as well as in the business centers, are coming into practice in every American town and city. A body of experts working on the loss of life and property due to insufficient street lighting found that a large city in the Middle West had lost an equivalent of $12,457,000 in thirteen years. Nearly $1,000,000 annually was the cost of darkness to the city alone. This figure does not take into account the inconveniences experienced by those who endured the streets with insufficient light.

Sunlight and Health.— In all probability civilized man spends more than half of his life within the doors of the home and his place of occupation. As civilization advances, the proportion of life spent within doors is continually increasing. Until recent years houses and factory buildings were constructed with very few windows for the admittance of sunlight. Indeed, the dwelling place of fifty years ago was constructed with small windows which were usually well curtained in order to prevent the fading effects of sunlight on rugs, carpets, wall papers, etc. Factories contained a few windows which were seldom, if ever, cleaned.

Within these darkened homes and factories tuberculosis and its allies held sway. In such homes tuberculosis frequently removed entire families. In factory regions tubercular troubles became rampant and grew to the proportions of a plague. Finally the people of the nation became alarmed over the losses

in human life. Every kind of "quack" remedy was sold as "a sure cure for consumption." Most of these remedies brought relief in the way of death.

Then scientists found that the action of sunlight destroyed the bacteria of typhus and tuberculosis. Diphtheria germs that were grown in cultures in dark places were destroyed when exposed to the rays of direct sunlight. The message of sunlight and its power to kill germs of harmful diseases went forth. But it was a hard lesson to learn, or the people thought it hardly possible and not worthy of practice. The action of sunlight on an invisible bacterium did not appeal to the minds of the people, for they continued to darken their homes and to make no improvements for the entrance of sunlight to the factories.

As time passed, the boys and girls in schools were taught the need of sunlight. Those boys and girls are the men and women of today who are in control of homes and factories. Some of the men and women must have learned and believed the things that they studied in the schools and universities or read in the papers and magazines, or heard from the lecture platform. For large numbers of these men and women have built homes with greater spaces given to windows, and factories whose walls and roofs are largely given to glass coverings. The invention of the steel window sash and the structural framework of steel supported by concrete made possible the using of large areas of outside walls for window openings. The external walls of some of the recent factory buildings are from 50% to 90% glass.

In the design of modern school buildings more wall space is being given over to windows. In most states laws have been passed requiring the window area to be at least 20% of the floor area, and furthermore that all the light shall come from one side of the room. In some states those in authority permit the light to come from both sides and the rear of the room. In this arrangement the teacher is compelled to work facing the light, and the pupils are annoyed with eye strain arising from cross lights.

The presence of sunlight in homes, schools, factories, shops, and public buildings is a great stimulus in keeping these places

clean and wholesome. The dirt, dust, wastes, and other forms of debris that may find a hiding place in the shadows of artificial light come into view when sunlight floods the room. In well regulated homes it is the habit to establish sanitary conditions by making provision for the entrance of large amounts of sunlight into all the living rooms.

Projects

1. To make a study of the lighting system in the home in order to determine whether or not it provides suitable illuminating effects.

Suggestion.—Converse with your parents concerning the three systems of lighting outlined in the chapter.

2. To design and make a table lamp in keeping with the requirements outlined in the chapter for portable lamps.

3. To design and make a floor lamp provided with direct and indirect lighting systems.

4. To make a study of the street lighting system of the community in order to determine whether it is sufficient for the safety of travel and for the protection of life and property.

5. To measure the candle power of the lamps used in the home.

6. To install a semi-indirect lighting system in one of the rooms of the home.

7. To make a survey of the home for the purpose of locating conditions that cause glare.

8. To remedy the causes of glare in the home.

9. To make a study of the various kinds of window glass.

Suggestion.—Make a collection of the various grades from the standpoint of surface (smooth, frosted, etched, sand blasted, etc.), color, reinforcements (some contain wires in their structures, etc.). State the purpose and use of each sample collected. The samples need be no larger than $2'' \times 4''$.

10. To make a study of the methods used in the manufacturing of glass.

Suggestion.—Display the raw materials and pictures of glass factories.

11. To make a study of the methods used for lighting photographic studios. Report in writing with drawings.

12. To make a study of the uses of prisms for the day lighting of basements and similar rooms to which daylight has no direct access.

13. To make a study of the colors used for window shades from the standpoint of reflection and absorption of sunlight.

14. To compare the cost per month for lighting the home with the cost of water, gas, food, laundering, carfare, etc.

CHAPTER XVIII

CONSERVING OUR EYESIGHT

Object.—To make a study of the eye, conditions governing its proper use, and its relation to health and comfort.

Life and Sight.—Man and the higher forms of animals are provided with special sense organs—sight, smell, hearing, taste, and touch. Some animals have one or more of the special senses very highly developed, while in others an organ of special sense may be in a very low state of development. In this connection one often hears such expressions as "blind as a bat," "keen scented as a hound," and "the unerring eye of the eagle." The high development of a special sense organ by the various classes of animals arises from the many centuries of use given to the particular sense organ which the animal finds the most serviceable to his manner of life. Many kinds of bats, but by no means all, have very small eyes. While the popular notion that bats are blind is incorrect, it has been found that they have other very acute senses which warn them of the presence of obstacles in their flight. When following the trail of a rabbit or a fox, the hound finds his nose more useful than his eyes. Down through the ages the hound has come to us with a wonderfully gifted sense of smell. The hound has eyes and ears, and he sees and hears exceedingly well. The eagle perched on the mountain top or in flight among the clouds needs a far seeing eye with accurate and trustworthy powers of vision. A multitude of centuries has endowed the eagle with an inheritance of a wonderful eye adapted to his manner of life.

Man has all five of the special senses in his possession. They are all well developed. He may not have a wonderfully developed sense of smell like the hound, or the far reaching powers of sight like the eagle, yet man uses his special senses with an accuracy that is unknown to animals.

Man ever has wanted to make greater use of his eyes, and it was to accomplish this purpose that he labored to bring forth his present-day methods of producing artificial light. As a result the highly developed artificial lighting methods of the present day have brought many new labors to the human eye. The great printing presses of the world are at work day and night turning out books, magazines, newspapers, and reading matter of every sort and kind. All of this printed material is intended for the eye. Schools, libraries, museums, theaters, and similar centers exist largely for the purposes of imparting information and amusement through the avenues of sight. Lighting effects of every sort and kind are brought into existence for the purposes of attracting and arresting the attention of the eye. So many labors have been assigned to the eye that, with the exception of the heart, it has become the busiest organ of the human body.

Eyesight is so important and so easily injured that too much care cannot be exercised in its conservation. The eye withstands abuse uncomplainingly over a long period of time. The eye makes no complaint directly from itself. It complains through other organs much of the time. When the breakdown comes, it is generally too late to effect a cure; and so temporary adjustments or remedies are brought into use. Eye strain and eye fatigue have become universal ills. The eyes may be misused under any condition if knowledge and care are not exercised, and it is deplorable that such misuse of the most useful sense organ of the body is so common.

In order that eye comfort and health may be the rewards of an intelligent appreciation, it is the purpose of this chapter to point out the relation of the eye to the light that it receives, the structure and working parts of the eye, and the conditions necessary for the best performance of its labors.

LENSES

Object.—To work with a convex lens in order to observe the effects produced in rays of light that pass through it.

APPARATUS.—Two convex lenses of different thickness. An assortment of spectacle glasses.

MATERIALS.—Candle. Thin sheet of writing paper or translucent paper.

PROCEDURE AND OBSERVATION.—1. Hold the thicker lens so as to allow the light from the sun to pass through to a piece of paper. Raise or lower the lens so as to bring the rays to the sharpest point. When you have found this point, you may name it the *principal focus*, or the *focal point*. The distance from the lens to the focal point is known as the *focal length*.

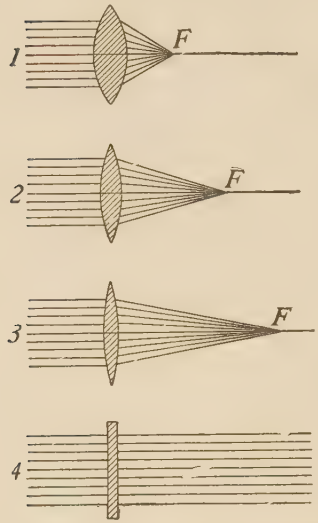


FIG. 191.—The thicker the lens the shorter is its focal length. (*From Tower, Smith, Turton, and Cope's Physics.*)

Look through the lens at a page of your text.

Holding the lens at various distances from the eyes look through the lens at distant trees and buildings. Does the image always appear right side up? While looking through the lens hold a piece of translucent paper between the eye and the lens. When the paper is properly adjusted, do you observe an inverted picture in the translucent paper?

2. Repeat (1) with the thinner lens. In which case is the focal point farther away from the lens? Compare your observations with those indicated in Fig. 191. Which lens has the greater converging power? Which has the shorter *focal length?* Make a rule

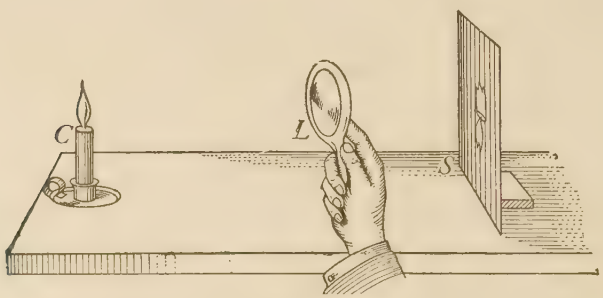


FIG. 192.—Position of lens for securing images of objects. (*From Tower, Smith, Turton, and Cope's Physics.*)

about the converging power of lenses. Make use of terms: *converging, focal point, thicker* or *thinner, focal distance.* It is not necessary to use all the terms in one definition, only those that you actually need.

3. Hold the lens between the candle and the paper as shown in Fig. 192. Adjust the lens and the candle so as to give the best possible image of the candle upon the screen.

Discover the conditions that produce an image larger than the candle; same size.

4. Repeat (1) and (2) with spectacle glasses. If the school is not provided with an assortment of spectacle glasses, mounted spectacles may be used, in which case two images will be observed in the place of one.

5. **Suggestion.**—If the physics department in the school is provided with an optical disk, other forms of lenses and combinations may be given simply as a demonstration exercise. The names of the forms may be learned during the demonstration.

6. Make a list of instruments in which lenses are used.

THE CAMERA (HOME PREPARATION)

Object.—To make a study of the construction and operating principles of a camera in order to know how "to take pictures" with it.

APPARATUS.—Any form of camera that may be found in the home. Those who have no cameras may arrange to study with those who have them.

MATERIALS.—Translucent paper or a thin sheet of writing paper.

PROCEDURE AND OBSERVATIONS.—1. Cameras are of two kinds—fixed focus and focusing. All box cameras and some folding cameras are fixed focus. The folding types that allow the lens holder to be set forth or back are focusing cameras. To which class does the one which you are studying belong? Focusing cameras have a scale of distances near the focusing device. Locate it and learn how to "set the lens" at any of the indicated distances.

FIG. 193.—Front lens. Shutter numbers above. Diaphragm numbers below.

2. Find the lens. On most focusing cameras there is a double set of lenses. Between the lenses are placed a *shutter* and a *diaphragm*. Remove the front lens in order to expose the shutter and diaphragm.

Do you observe two set of numbers and letters printed above and below the lens opening? One set of letters are for governing the shutter; the other, the diaphragm. Set one of the levers at *T*. Press the bulb several times. You are operating the shutter. Set the lever at *B* and again press the bulb. Adjust the lever to various other positions and operate the bulb at each position. In what position does the shutter remain open? In what positions did the shutter "snap"?

Place the shutter lever at *T* and open the shutter. Move the diaphragm lever. Does the opening in the diaphragm grow smaller or larger as the

diaphragm lever is moved forward and backward? Does the diaphragm regulate the amount of light that enters the camera?

Are both the shutter and the diaphragm essential to the operation of a camera? Explain.

When you replace the lens be sure that there are no finger prints on either surface. If there are such marks, remove them with a piece of

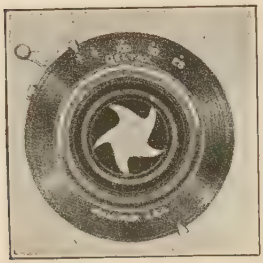


FIG. 194.—Lens removed and showing shutter partially open.

FIG. 195.—Lens removed and showing diaphragm partially closed.

silk or other fabric that will not scratch the surface of the lens while polishing.

2. Remove the back of the camera and by means of rubber bands cover the opening thus made with translucent paper. Point the camera out of doors and while observing the paper snap the shutter. Adjust the shutter and the diaphragm to various rates and openings and repeat the observation. Focus the camera on far and on near objects. Is the lens near the paper or farther away when focusing on nearby objects?

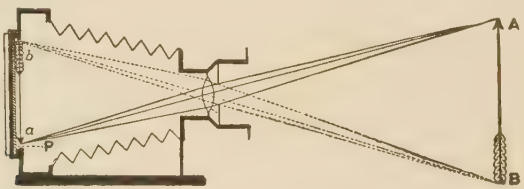


FIG. 196.—Cross-section of a camera showing the formation of the image upon the plate.

Make a cross-section drawing of a camera and explain briefly the use of each part (as shown in Fig. 196).

3. Making the negative. (See part 5 of this experiment.)

Demonstration

In every class there are usually one or more pupils who have already developed negatives and printed pictures.

If the class room can be darkened arrange for a demonstration on the part of one or more pupils. The developing powders may be purchased

in tubes ready for use when dissolved in water. There are four complete steps in the development of the negative:

(*a*) developing and rinsing with water,
(*b*) fixing,
(*c*) washing,
(*d*) drying.

Demonstration

4. Printing the positive. If negatives previously prepared are used, it is possible to make the positives during the same class period in which the negatives are made.

5. When class rooms can not be sufficiently darkened, or time does not permit, the printing and developing of the blue prints from negatives already made may be demonstrated. Those who wish to learn to develop negatives and print the regular pictures may make arrangements to visit and learn from those who have home facilities for developing and printing. Where the work is thus done it may be reported in the form of a project.

THE EYE

Object.—To make a study of the structure of the human eye for the purpose of being better informed regarding the formation of right habits of use and care.

APPARATUS.—Model of human eye, or wall charts showing the structure of the human eye.

MATERIALS.—Library references. Texts on physiology. Magazines and pamphlets containing articles on the care and use of the eye.

PROCEDURE AND OBSERVATIONS.—1. If the school possesses a model of the eye make a study of the arrangement of parts and structures as shown by the model. Learn the names of each part as indicated on the accompanying card.

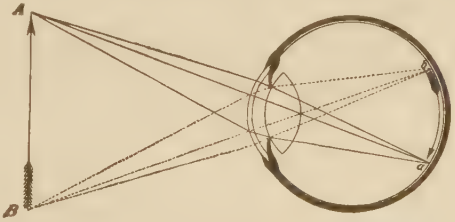


FIG. 197.—Cross-section of the human eye showing formation of the image upon the retina. (*From Brubaker's Text Book of Physiology.*)

2. If the school does not possess a model of the eye, make a study of a wall chart or Fig. 202 in this text. Observe the arrangement of the principal parts and their relation to each other. Find the iris, the lens, the retina, and the optic nerve. Find the two humors that fill the spaces before and behind the lens. They give shape to the eye and aid in holding the working structures in their proper positions.

3. Compare the camera in every detail as to structure with the eye.

4. By means of a looking glass make a study of your eye.

(*a*) Why is the eye protected by the eyebrow? Does the eyebrow shade the eye from the light coming from above?

(*b*) Of what use is the eyelid? The eyelashes?

(*c*) Standing out of doors in strong sunlight observe the opening in the iris. Repeat the observation indoors in a room semi-darkened. Give the reason for the observed changes. Of what use is the iris?

(*d*) What colors may the iris have for different persons?

5. In physiologies and library references look for and read articles concerning the proper and improper uses of the eye. What is meant by "hygiene of the eye?"

6. Report your work in a briefly written theme. Use drawings, if you find them useful.

Lenses and Their Uses.—Since the opening into the crystalline lens of the human eye is never greater than about one-quarter of an inch, the total amount of light entering the eye is never great. Consequently, only those objects within the range of human vision are clearly seen. The Greeks and Arabians when studying the stars had to be content with whatever information could be gained with unassisted eyes. Down through history writers lament the fact that man's power of vision is so limited, and not until 1610 did man find a way of extending the boundaries of his vision farther out into space. In that year Galileo invented his telescope, which was constructed on the plan of our opera glass of the present day. The lens in Galileo's telescope had a diameter of $2\frac{1}{4}$ inches or an area about 81 times greater than the opening into the eye. With the aid of this instrument 81 times more light was gathered from a star and brought to focus on the retina. When directed toward the moon, this telescope revealed its mountains, plains, and valleys; and when directed toward Jupiter, revealed the four satellites in motion about it. Hence it is not too much to say that Galileo's telescope completely changed the course of human thought.

Now that lenses were brought into use as aids to the eye, many forms and sizes were manufactured and employed in newly devised instruments of every sort and kind. At first lenses were used in telescopes for astronomical and terrestrial purposes. Then came the custom of using lenses before the eyes while one is reading, and small lenses fitted in frames came

into use as eye glasses. When photography became an art, the lens found a place in the camera for purposes of making pictures. Today the art of making lenses and optical instruments has become one of the most specialized industries of the world. From what has been said, it will be observed that lenses of every kind are for purposes of aiding the human eye. The lenses in the moving picture machines, the microscope, and the light-house lantern are all for the purpose of assisting the eye.

Classes of Lenses.—There are two classes of lenses—those thick in the middle are *convex*, while those thick at the edges are *concave*. All lenses that are classed as convex are converging lenses—that is, they bring the light that passes through them to a point. (See Fig. 198.) The lenses classed as concave diverge the rays of light that pass through them. (See Fig. 199.) As shown in Fig. 200 there are six possible forms of lenses: (1) double convex, (2) plano convex, (3) concavo convex, (4) double concave, (5) plano concave, (6) convexo concave. As shown in the illustration, the first three lenses are thickest at the center,

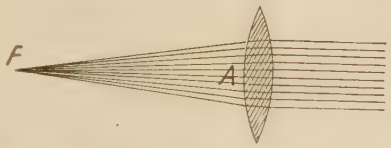


FIG. 198.—A convex lens brings the light to a focus.

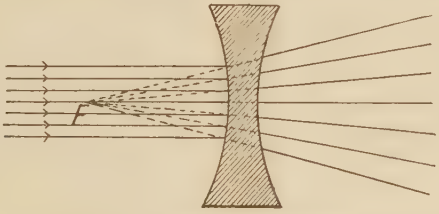


FIG. 199.—A concave lens disperses the light.

and hence are converging toward light; the last three appear thickest at the edges, and hence are diverging toward light.

When any convex lens is held in the sunlight, the shaft of light that passes through is brought to a very sharp point. This point is called the *principal focus* or focal point of the lens. The distance from the *focal point* to the center of the lens is known as the *focal length* of the lens.

A shaft of light passing through a concave lens is always more diverged after passing through than before it enters. Concave lenses are used with convex lenses in several kinds of optical instruments and eyeglasses for the correction of near-sightedness.

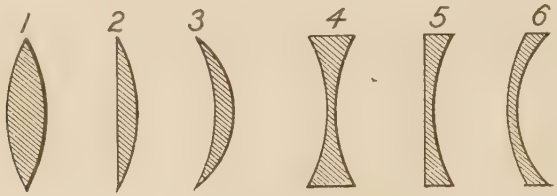


FIG. 200.—Forms of lenses.

The Opera Glass.—The opera glass consists of an arrangement of convex and concave lens (as shown in Fig. 201). The convex lens is the objective, and the concave lens is the *eyepiece.* The objective lens gathers the light from the distant object and converges the rays as they pass toward the eye. The concave

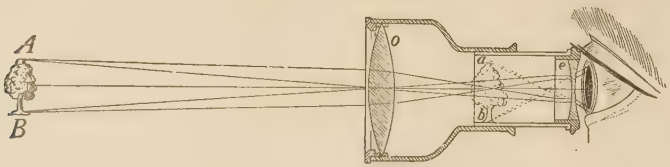


FIG. 201.—Formation of an image by an opera glass. *a–b* is the virtual image. (*From Tower, Smith, Turton and Cope's Physics.*)

lens prevents the formation of an image by slightly diverging the rays before they enter the eye. As a consequence the observer sees an upright image of the object. The effect is to make the object appear near and at the same time more distinct.

The Eye and Its Structure.—In the forepart of the human skull are located two deep cavities or receptacles in which are located the organs of sight. These orbital cavities are lined with fluid-secreting membranes and well cushioned with tissues of fat that fill out the spaces not occupied by the eyeball. Thus nicely set in its pocket-like bed, the muscles that hold the eye in place are able to adjust the ball so as to receive the light from many angles. The eyelids serve as curtains which are able to

enclose and protect the forward portion of the eye. When open the eyelids and their lashes frame the eye in a manner that gives it an agreeable and attractive appearance.

The eye is a spheroid in shape, measuring about one inch in diameter. As shown in Fig. 202 the wall of the eyeball is made up of three coats or tunics—the *sclera* (*sclerotic coat*) or outer coat, the *choroid* or middle coat, and the *retina* or inner coat. Contained within these coats are three transparent bodies—the *aqueous humor*, the *crystalline lens*, and the *vitreous humor*.

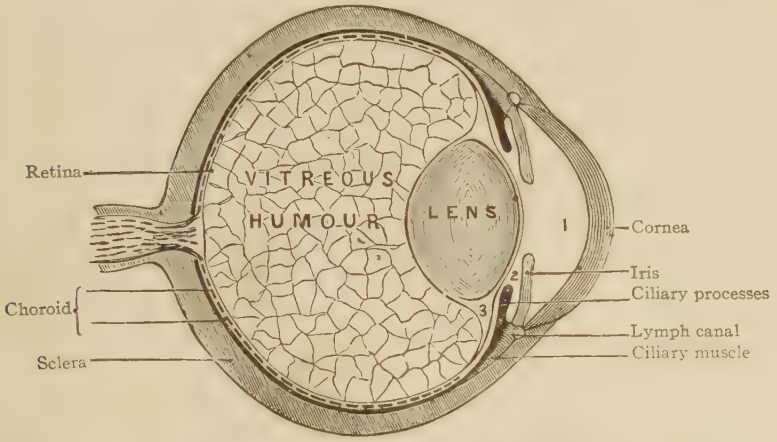


FIG. 202.—A section of the eye. (1) Anterior chamber; (2) posterior chamber. The aqueous humor occupies the two chambers. (*From Bundy's Anatomy and Physiology for Nurses.*)

The *sclera* is the "white" of the eye, of which greater or smaller portions are always in view. It is dense and tough, protecting the more delicate and sensitive portions within. In the front part of the eye the sclera changes into the *cornea*, which, like the sclera, is tough and firm, but perfectly transparent in order that light may enter the eye. The front portions of the sclera and the cornea are covered with a sort of mucous membrane bearing a network of very fine blood vessels which can be easily seen when swollen from any cause whatsoever.

The middle coat—the choroid—is neither dense nor tough and is composed of a network of very minute blood vessels. It has a deep brown color which causes the inner chamber of the eye to be dark. Of course, the choroid coat does not exist in the front

portion of the eye. Here it is replaced by the *iris*—a beautifully shaped curtain with a hole in its center which regulates the passage of light into the inner chamber of the eye.

The *retina*, the innermost coat, is a very delicate structure in which are the beginnings of the *optic nerve* fibers. It is this layer which is essential to vision—no retina, no vision. Like the sclera and the choroid layers, the retina does not extend across the front of the eye. The rays of light which fall upon the retina must first pass through the *cornea*, *aqueous humor*, *crystalline lens*, and *vitreous humor*. Each and every one of these bodies must be perfectly transparent, otherwise vision would be impaired and perhaps lost. The space between the cornea and the lens is divided by the iris into two portions, the *anterior* and *posterior chambers*. These chambers are filled with a thin clear fluid—*aqueous humor*—which serves to float the *iris* and give shape to the cornea.

The Eye, Nature's Optical Instrument.—The eye is essentially a living camera in which, by means of a lens, the images of things about us are formed upon the retina. In the camera the image is brought to a focus upon a sensitive plate, which must be given a great deal of time and patient labor before an actual picture can be had. Indeed, the making of a picture by means of a camera and its sensitive plate is such a tedious operation that few people ever take the time to master the many details concerned in the process. In this respect the eye is greatly superior to and far more wonderful than the camera. In health the eye is always exposed and ready to receive the images of objects. No matter whether the object is close at hand or more distant, the fluid-like lens of the eye is so controlled as to focus the images of all upon the sensitive surface of the retina. When the images are distant, the lens of the eye is made thinner; when the objects are near at hand, the controlling muscles make the lens thicker. Hence the images of objects far and near are kept in perfect focus upon the retina. This arrangement on the part of nature for decreasing and increasing the thickness of the lens for focusing images is controlled by a set of muscles and nerves which are delicately and accurately adjusted to the needs of the eye.

It is the retina that does the real work of the eye. This delicate sheet-like membrane is composed of a nervous tissue which is closely connected to the brain by means of the optic nerve. The retina receives the various image-pictures focused upon it and passes them on to the optic nerve and brain with a swiftness and accuracy that no man-made device has yet been able to equal. Throughout the day the retina is receiving constantly a countless number of impressions. Scenes full of all kinds of objects, some at rest and others in motion, are all accurately reported as to form, color, position, action, and changes of whatever kind. How wonderful, then, is the retina when compared to a photographic plate that is only capable of a single picture! So important is the retina that it may be claimed that every other part of the eye exists in order that the work of the retina may be well done. Without the lens no picture will be formed upon the retina. The iris must admit the proper amount of light, for too great amounts produce blinding effects from which the retina is slow in recovering.

The Eye and the Work of the World.—In the days of the hand loom and the ax, things moved no more rapidly than the muscular forces of the body of man were able to drive them. Under such conditions muscular systems of the arms, back, and legs felt the wearing effects arising from the day's toil. Whatever machines existed moved slowly and in no way caused excessive fatigue of the eye. The slow and plodding water wheel drove the flour mill or saw-mill with a speed that was in no way great.

From that time to this, things have become gradually different. Machines of every sort and kind are driven at a high rate of speed by the untiring forces that arise from steam and electricity. In the operation of these machines quickness of eye and nimbleness of hand and fingers are largely essential. In short, the machines that perform the labors of the world need the guidance of a human eye—an expenditure of nervous energy in the place of muscular energy.

While bodily weariness may arise from either fatigued muscles, or fatigued nerves, or both, the effects arising from the two kinds of exhaustion are quite different. Throughout the

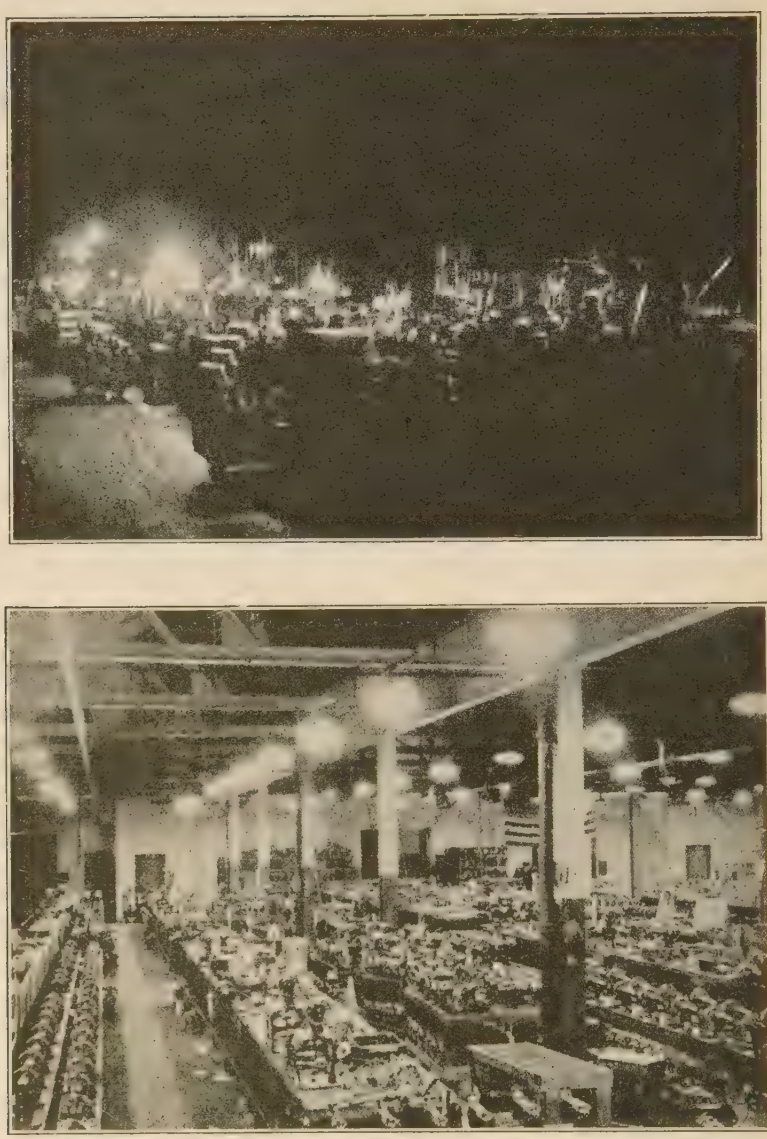


FIG. 203.—Adjoining rooms in the same factory. The upper figure illustrates a strictly local lighting system of the poorer sort. The lower figure illustrates a lighting system consisting of 150-watt bowl enameled lamps equipped with dome reflectors spaced 10 feet apart; the average illumination is 9 foot-candles. (*Courtesy of General Electric Co.*)

existence of man his muscles have been used for the performance of heavy labors. Food and short periods of rest usually restored the muscles, and they were again ready for the following day's work. Restoration from nervous fatigue is not so easily accomplished, for the reason that the nervous system is more centralized, closely related to every portion of the body, and not adapted to rapid recovery. Furthermore, a person weary from tired muscles usually knows what the trouble is, while one weary from nerve fatigue is sensitive and restless and very often does not take the required period of rest and quietness.

Owing to the close relationship of the eye to the brain and nervous system, many nervous disorders have their origin in the eye. Eye strain arises from the prolonged observation of polished surfaces, or moving parts of machinery, glare of strong lights in the field of vision, and constant focusing of the eye upon fine objects. Continued eye strain is the cause of a great number of nervous disturbances, such as headache, dizziness, nausea, and general nervous debility.

Relief from eye strain is obtained by frequently resting the eyes by looking at distant objects, bathing the eyes in cold water, and improving all measures that have to do with general health. Many of the better manufacturing industries have found that it pays to improve the conditions of illumination (see Fig. 203) and to shorten the hours of those laborers whose duties are particularly fatiguing and the cause of eye strain. Daily recovery from eye strain depends largely upon the general habits of life of the individual, who should select proper foods, bathe frequently, and live in a well illuminated and properly ventilated home in a district of comparative quietness. Otherwise the nervous disorders arising from eye strain will become more and more deep seated.

Common Defects of the Eye and Their Correction.—In the normal eye the focus is at the retina, upon which are clearly formed the images of objects that are far or near. This accommodation is accomplished by the muscles that control the lens of the eye. However, when a small object is held too close to or too distant from the eye, the object is not seen clearly

by a normal eye. In this respect one can experiment for one's self with any small object. When a pencil is held very near to the eye and slowly moved away, a position will be found where the image is very clear. This position is the *near point of accommodation.* When the pencil is carried farther away, a point will be found where it can no longer be seen clearly. This is the *far point of accommodation.* The distance between these two positions is the measure of *the range of accommodation.*

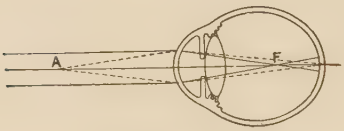


FIG. 204.—Near-sightedness. The image is brought to a focus between the lens and retina. (*From Tower, Smith, Turton, and Cope's Physics.*)

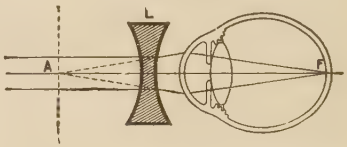


FIG. 205.—Correction of near-sightedness by concave lens. (*From Tower, Smith, Turton, and Cope's Physics.*)

However, in some eyes the retina is so far away from the lens that the muscles of accommodation fail to flatten the lens sufficiently. Consequently the image is formed before it reaches the retina (see Fig. 204). Such an eye is called near-sighted, and its defect is corrected by the use of concave glasses (see Fig. 205). A near-sighted eye generally has clear vision of very near objects, while images of distant objects appear blurred and indistinct.

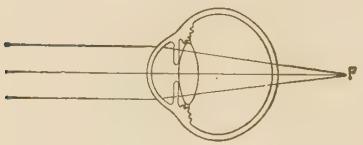


FIG. 206.—Far-sightedness. The image is brought to a focus back of the retina. (*From Tower, Smith, Turton, and Cope's Physics.*)

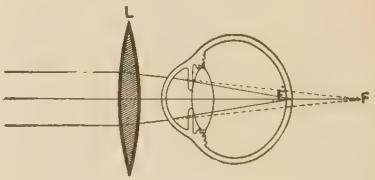


FIG. 207.—Correction of far-sightedness by a convex lens. (*From Tower, Smith, Turton, and Cope's Physics.*)

On the other hand the eyeball may be too short and the image brought to a focus at a position beyond the retina (see Fig. 206). Eyes so affected are known as far-sighted and are corrected by the use of convex lenses (see Fig. 207).

The above defects all arise from a question of distance between the lens and the retina. As pointed out, far-sighted

and near-sighted defects are easily corrected by making proper uses of convex or concave glasses. Another and frequently more serious trouble, known as *astigmatism*, arises when the curvature of the cornea is not perfectly regular. The curvature of the surface of a normal cornea is like that of a perfect ball. However, when its surface has a curvature like that on the side of a lemon, the light rays are so affected as to prevent the lens from producing a perfect image on the retina. The effect of astigmatism reveals itself in an inability to see with equal clearness the lines running in different directions. Thus some of the lines in Fig. 208 will be sharply defined and black, while others will appear blurred and lighter in color. The defects caused by astigmatism are corrected by the use of "cylindrical" glasses.

FIG. 208.—Test, card for astigmatism. (*From Tower, Smith, Turton, and Cope's Physics.*)

Far-sightedness, near-sightedness, and astigmatism all contribute to eye strain, which in its turn results in severe headaches and other general disturbances of health. When the defects are corrected by the use of properly fitted glasses, these ills are greatly and very often completely relieved.

The Eye and Its Relation to the Conditions of Health; a Summary.—Health is a condition of the whole body in which all the important parts are sound and in good working condition. A body in good health does its work without pain and with ease. Disease is a condition in which one or more organs are affected with disorders which interfere more or less seriously with the welfare of the whole body. An organ may not be able to perform its part of the labors of the body without causing a good deal of pain. Inability on the part of the eye may arise from the following conditions:

1. Deep seated defects within the organ of sight, such as far-sightedness, near-sightedness, astigmatism, and others beyond the consideration of this course.

2. Unfavorable external conditions, such as glare, too strong or too weak sources of light—in short, improper illumination.

3. Misuse and improper care, such as forcing the eye over long periods of close focusing—reading, sewing, setting type; movement in the field of vision, as in travelling and seeing moving pictures; drugs and narcotics; and in general all conditions that give rise to a state of impaired health.

How Conditions of Health Affect the Eye.—While the eye greatly influences conditions of good health, it must not be thought that general conditions of health have no effect upon the eye. By reason of its very delicate structure and its intimate relationship with the brain and the nervous system, there is scarcely any affection of a general nature that does not react upon the eye. Diseases of the blood—anæmia, disorders of the veins and arteries, or the presence of poisons in the blood resulting from disturbances in the kidneys, Bright's disease—all affect greatly the health of the retina. Diabetes seriously affects the crystalline lens. Infectious diseases, such as measles and scarlet fever, are likely to leave very marked effects in the cornea and generally weakened eye structures. Before the days of vaccination, it has been estimated that 35% of all cases of blindness resulted from smallpox; today the proportion ranges from 2% to 3%. Disorders of the nervous system, meningitis, and hysteria, all manifest themselves in disabling to some degree the organ of vision. It is beyond the scope of this course to give in detail the complications that may arise from all fevers resulting from infectious diseases and disorders of health. Enough has been pointed out to emphasize the importance of health for the maintenance of good vision.

The Care of the Eye.—In the care of the eyes the best advice of skilled experts is necessary. In health the normal eye is a wonderfully adjusted instrument. When defects do occur, it is more than useless to select glasses by merely testing the vision with test cards. Imperfect methods of securing information regarding the condition of the eyes can in no way select the best lens for defective sight. The use of wrong glasses is simply adding another defect to the one already present, which often does more injury than using no glasses at all. If vision

is indistinct, or if the eyes tire quickly when employed at close work, or if one suffers frequently from headaches and states of nervousness, it is best to seek competent medical advice.

Much has been said already about proper illumination and its relation to the eye. It remains to be said that little can be done for any eye, normal or abnormal, where improper methods of illumination persist. The eyes are of too much importance to use for the reading of books and papers of small type, of glossy surfaced paper, or of cheap grades of paper and poor print.

Like every other organ of the body, the eye may be kept strong and sound by giving attention to the general health and welfare of the body. Muscular exercise through work and play, rest and sleep, good air and wholesome water, proper food and regular removal of waste materials, bathing and other hygienic habits, all aid and help to keep the eyes in proper condition. Travelling, sight-seeing, watching moving pictures, reading newspapers, and similar pursuits during recreational hours must not be regarded as rest periods for the eye, for during such activities the eye is doing its hardest kind of work. The maintenance of good health is essential to the maintenance of strong and sound eyes.

Projects

1. To make a pin hole camera and to demonstrate its principles of operation.
2. To learn how to make lantern slides.
3. To make a projecting lantern for home use.
4. To study the history of one or more of the large telescopes and their uses.
5. To make a study of the construction and principles of operation of a prism binocular.
6. To make a study of the construction and principle of operation of a compound microscope.
7. To study the history of the development of the art of photography.
8. To make a study of a motion picture camera.
9. To make a study of a motion picture machine.
10. To make a study of color photography.
11. To correspond with The Eye Conservation Council of America, Times Building, New York City, for literature relative to the "Conservation of Sight."
12. To find out what is meant by the defect commonly known as "Color Blindness."
13. To collect and display the advertising literature of "quacks and fakes" who make extravagant claims concerning their ability to correct defective vision.

14. To write a paper setting forth five or more principles relative to the maintenance of good eyesight.

15. To write a paper on "A visit to an oculist."

16. To write a paper on "The proper care and uses of one's eye glasses."

17. To write a paper setting forth the proper and improper adjustment of eye-glasses before the eyes.

Suggestion.—Deal with such topics as: lenses too low; out of alignment; bent frames; incorrectly inclined; lenses too small for the eyes, etc.

18. To obtain and to learn how to use a standard vision card in order to test the eyes of the various class members or the members of the family for determining the presence or absence of near-sightedness, far-sightedness, and astigmatism.

UNIT V

NATURE'S STORE OF ENERGY AND MAN'S MEANS OF CONVERTING IT TO HIS SERVICE

CHAPTER XIX

MAN'S WORK AND HIS NEED OF TOOLS AND MACHINES

Object.—To make a study of man's need of tools and machines in the performance of his work.

To make a study of the advantages arising from the use of machines in the performance of labor.

The Necessity of Tools.—When we compare man with other animals of the earth, we find him to be one of the most defenseless creatures known to science. He possesses neither horns nor fangs, claws nor hoofs, hard outer shell nor poison glands. However, we find man endowed with an intellect that is capable of designing artificial weapons for defense and attack, and also with a hand so shaped that it may become skilled in the use of such weapons.

The spear and the bow and arrow were early brought to a high degree of perfection. Axes and knives, which were improved from time to time, served their best purpose when man learned to produce them from metals. When man learned to till the soil and to build more substantial homes, many different kinds of tools became a necessity. At first these tools were crude and costly, but as each century passed by, improvements in design and methods of manufacture were brought about. As each new and improved instrument was more serviceable than the old, man built better with less expenditure of the strength of his body and thus found himself more secure against those forces of nature that opposed him.

The conditions mentioned above are hard to realize, for today we are in the habit of visiting shops that are well stocked with

a thousand and one instruments of every variety and kind. Should we be very exacting and want some special instrument, the shopkeeper would provide us with it in a short time by having it made or sent from some distant market. And thus the wealth of tools and machinery on every hand makes it impossible for us to realize the great struggle that would be necessary for the meanest sort of a livelihood in a machineless world. Our present-day life is, then, complicated with the use or products of an infinite number of machines. In order that we may understand and better appreciate the mechanical world about us, some of the simple machines that we find in daily use in our homes and community are here considered as the object of our study.

RESISTANCE TO WORK (HOME ACTIVITY)

Object.—To learn the nature of the forces that oppose us when we work.

APPARATUS.—Spring balance.

MATERIALS.—A small board having one surface finished and the other unfinished. Some weights, or bricks, or flat irons. A piece of twine or string. A tack or small nail.

PROCEDURE AND OBSERVATIONS.—(*a*) GRAVITY.—Examine the spring balance and see how it is made. Is it possible to weigh in ounces and pounds?

Tie a string around each of the weights or bricks and find their weight in pounds and ounces. Using a piece of chalk or a pencil write the weight on each object. Weigh other objects found about the room.

Can you find any objects that do not possess the property of *weight?*

The earth attracts every object and particle wherever located. This force of attraction between the earth and any other object, whether it is a solid, a liquid, or a gaseous body, is known as the force of *gravity*. And so, when we weigh a body, we are simply measuring the earth's attraction for the body. In other words, we are measuring in ounces and pounds the force of gravity between the earth and the body which we are weighing. In the metric system we measure the force of gravity in grams and kilograms. When we lift weights from one level to another, what force is constantly resisting or opposing us?

(*b*) FRICTION.—Attach a string to one end of the board by means of a tack, and the other end of the string to the hook of the spring balance.

Place the board with its rough surface downward and observe the force required to draw it over the floor or other surface. Compare the force required to drag the board with its weight and note which is the greater.

Repeat the experiment with the finished face of the board as the rubbing surface. Compare results with those obtained when using the rough face of the board as the rubbing surface.

Place a brick on the board and repeat the experiments. Compare the force required to drag the load, with the weight of the load (sum of the weights of the board and brick).

Repeat the experiment with a load of two or more bricks.

When you increase the load do you increase the rubbing effect between the surfaces of the board and floor?

The rubbing of the two surfaces against each other is called *friction*, and it is equal to the force required to slide the load along over the face of the floor.

Did you observe that the force required to start the load was always greater than that required to keep the load sliding? If not, repeat the last trial. Is *starting friction* greater than *sliding friction?*

When will the friction between two rubbing surfaces be the greater, when they are smooth or when they are rough and irregular?

Would polishing the surfaces reduce the friction?

Place two or three lead pencils under the board and repeat the experiment. Is sliding friction greater or less than *rolling friction?* Why are ball bearings used in bicycles and roller bearings in automobiles?

Why and when are lubricating oils used in machines?

Why are jewels used in watches?

Write a statement describing the ways suggested in this experiment for reducing friction.

Can we ever get rid of all the friction or will some always remain?

(*c*) INERTIA.—Place one or more books on a sheet of paper which lies on a table top. Firmly grasp one end of the paper and give it a sudden jerk. What happened? Repeat the experiment and see if you can remove the paper with very little disturbance to the books.

Repeat the experiment with a slow steady pull. Do the books ride along on the paper? Does it require some time to change bodies from a state of rest to a state of motion? Can moving bodies be suddenly brought to rest? Does it take time to put a loaded car in motion? Can a swiftly moving car be brought to sudden rest?

That property of a body to remain at rest when at rest or to remain in motion when in motion is called inertia.

(*d*) APPLICATIONS.—Are the forces arising from *gravity*, *friction*, and *inertia* always opposed to us or are they sometimes necessary and useful?

Suggestions.—Why place sand on slippery pavements?

How is the slipping of street car wheels prevented?

Why are brakes placed on machinery? Do they make use of friction in any manner? Explain.

What order would there be in a world where there was no constantly acting force similar to gravity?

Do we make use of gravity when weighing out the foods and various other articles which we buy and sell?

Why are we able to balance ourselves so easily on a bicycle when it is in motion, and not so easily when it is at rest?

Is it easier to keep a train of cars in motion on a level track or to start them from a state of rest to a state of motion? Explain.

Why are large and massive fly wheels used on gas and steam engines, grinding machines, and foot presses?

Why is the distance greater in a running broad jump than in a standing broad jump?

DOING WORK WITH THE AID OF LEVERS

Object.—To work with the lever and to discover wherein it is an aid in the performance of work.

Apparatus.—Seesaw board, scissors, pinchers, pliers, tin snips or metal shears, straight bar, meter stick or yard stick, weights with wire hooks or twine loops.

Procedure and Observations.—(*a*) The Seesaw—Observe a seesaw board. How is it supported? The support or rest is called the *fulcrum*. Does the seesaw turn on the fulcrum? *Any rigid bar free to turn on a fulcrum is called a lever* (see Fig. 217).

When two boys of equal weight get on the seesaw, where do they place themselves? Do they take equal distances from the *fulcrum* or turning point? Why?

When a small boy seesaws with a large boy, which has the longer arm of the seesaw? Why?

If one boy is twice as heavy as the other, where will the light weight boy sit? Where will the heavy weight boy sit? Why? Which would go the higher? How much higher? Which would go faster? How much faster?

If a boy wanted to balance a stone one-half as heavy as himself on the seesaw board, where would he place the stone and where would he sit? Which would have the longer arm? How many times longer?

If a stone weighs 50 lb. and the boy weighs 100 lb. and he sits five feet from the fulcrum, how far out must the stone be placed on the other side of the fulcrum to balance the boy? Test your answer as follows:

$$\text{Boy's weight} \times \frac{\text{his distance}}{\text{from fulcrum}} = \text{Stone's weight} \times \frac{\text{Stone's distance}}{\text{from fulcrum.}}$$

When a lever is properly balanced, the product of one weight and its distance from the fulcrum on one side is always equal to the product of the other weight and its distance from the fulcrum.

Could a boy who can press only 75 lb. move a stone weighing 300 lb. with a lever that is 5 ft. long? Make a drawing showing the arrangement

of boy, stone, and fulcrum. How long would the boy's portion of the lever be? How long would the portion on the side of the stone be?

(*b*) HOUSEHOLD LEVERS.—Examine a pair of scissors. It is really two levers which have the same fulcrum, the rivet, about which the two levers turn. Cut a piece of cloth placed near the points. Cut a piece of cloth placed near the rivet, or fulcrum. In which case is it easier to cut the cloth? Why?

Examine the pliers, or the pincers, or the metal shears. Why have they long handles and short jaws? What serves as the fulcrum? How many times longer is the handle than the jaw? If the handle is 10 times longer than the length of the jaws, what is the advantage when using this instrument or machine? Why are the handles of pliers or scissors called the *force arms?* Why are the jaws of pliers or scissors called the *weight arms?*

(*c*) THE THREE CLASSES OF LEVERS.—The seesaw and scissors are examples of a lever that always has the fulcrum or turning point somewhere between the force and the weight. Consult Fig. 217 and observe the three ways in which the force, *F*, the weight, *W*, and the fulcrum, *O*, may be arranged.

By means of the straight bar or meter stick lift a weight as shown in (*a*) Fig. 217. Call *OF* the force arm and *OW* the weight arm. When is the force less than the weight? When is the force greater than the weight? When the fulcrum is placed between the acting force and the weight, we have a lever of the first class.

Arrange the acting force, the weight, and the fulcrum as shown in (*b*) Fig. 217. Is it possible to have a weight arm, *OW*, longer than the force arm, *OF*? Is the acting force always less than the weight? In this arrangement we have a lever of the second class.

Arrange the fulcrum, the acting force, and the weight as shown in (*c*) Fig. 217. In this arrangement is it possible to have a force arm, *OF*, longer than the weight arm, *OW*? Is the acting force always greater than the weight? When is the acting force twice as large as the weight? When we use this type of lever, which moves the faster, the acting force or the weight? In this arrangement we have the third class lever.

HOME WORK.—To what class of levers do the scissors belong? Find two other examples of this class in your home and community. Make a simple drawing of each and label the acting force, *F*, the fulcrum, *O*, and the weight or resistance, *W*.

To what class of levers does the wheelbarrow belong? Locate two other examples of this type. Make drawings and label forces as directed above.

To what class of levers does the shovel belong? Locate two other examples of this type of lever. Make drawings and label force as directed above.

MEASURING WORK AND USEFULNESS OF MACHINES

Object.—To learn how to measure work and how to calculate the usefulness of a simple machine—the pulley.

Apparatus.—Two single pulleys, 2 double pulleys, a weight, a stout cord, a spring balance, a yard stick.

Procedure and Observation.—(*a*) Fixed Pulley.—Fasten one end of the cord to the weight and pass the cord over a fixed pulley as shown in Fig. 209.

What acting force is required to raise the weight? How does the acting force compare with the weight? Why is the acting force greater when

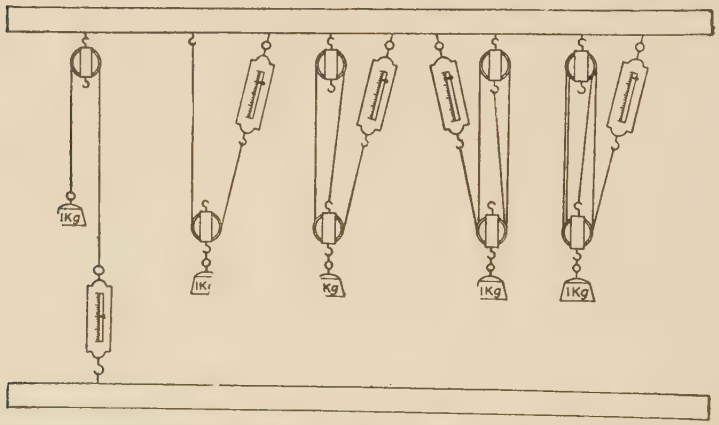


Fig. 209.—Arrangements of pulleys. (*From Ahrens, Harley, and Burns' Practical Physics Manual.*)

raising than when lowering the weight? Is there any way of lessening the friction in the machine?

When we raise a *one pound weight one foot* we are doing *one foot-pound of work*. Likewise when a *force of one pound* passes through a *distance of one foot, one foot-pound of work* is being performed. When a *two pound force* has passed through a distance *of three feet, six foot-pounds* of work have been done. In short,

$$\text{Work} = \text{Distance} \times \text{force, or}$$

$$\text{Foot-pounds of work} = \text{Distance in feet} \times \text{force in pounds.}$$

Letting W stand for work in foot-pounds, D for distance in feet, and F for force in pounds, we may write

$$W = D \times F$$

This expression is called the *equation of work* or simply the *work equation*.

By means of the spring balance find what force is required to raise the weight two feet.

When the weight is raised two feet how far does the acting force travel? When the weight is raised three feet does the force descend a distance of three feet? Is this arrangement of a fixed pulley and rope ever used to raise weights? Give instances. Study the following statements:

(*a*) Work received = weight × distance.
(*b*) Work spent = acting force × distance.

Why is *work spent* always greater than work received? When we use machines, is some work always wasted in overcoming friction? Upon what condition does the efficiency or usefulness of a machine depend?

Calculate the efficiency of the fixed pulley by dividing the number of foot-pounds received by the number of foot-pounds spent.

$$\frac{\text{Work received}}{\text{Work spent}} \text{ or } \frac{\text{Weight} \times \text{distance}}{\text{Acting force} \times \text{distance}} = \text{Efficiency of machine.}$$

Is it possible to have a machine 100% efficient? Explain.

(*b*) Movable Pulley.—Arrange the pulley, the weight, and the rope as shown in Fig. 209(*b*). What force is required to raise the weight? Is this an advantage? How far does the force travel to raise the weight one foot? How does the work spent compare with the work received? Calculate the efficiency of the movable pulley as directed above when working with the fixed pulley. What force would be required to raise a weight of 100 lbs?

(*c*) Combinations of Pulleys.—Arrange two single pulleys, rope, and weight as shown in Fig. 209(*c*). What force is required to raise the weight? Why is not the acting force exactly equal to one-half of the weight? How many ropes support the weight? Has the *number* of ropes any bearing on the amount of force required to raise the weight? If there were no friction would the force be exactly equal to one-half of the weight? Why? Why does the force move twice as far as the weight? Is this arrangement of pulleys and ropes ever used to lift weights?

Calculate the mechanical advantage by comparing the weight with the force as follows:

$$\frac{\text{Weight}}{\text{Force}} = \text{Mechanical advantage.}$$

Calculate the mechanical efficiency as follows:

$$\frac{\text{Weight} \times \text{distance weight traveled}}{\text{Force} \times \text{distance force traveled}} = \text{Efficiency of machine.}$$

Repeat the experiment using an arrangement of pulleys and ropes and forces as shown in Fig. 209(*d*) (*e*).

Questions.—Observe whether pulleys are used in the window frames of the school and home. Explain the importance of this use of the pulley.

Where else have you observed pulleys in use? Suggest instances in which a "block and tackle" might be brought into service.

Do you consider the pulley a machine of much importance? Give reasons for your answer.

When is work done?

If a man endeavors to lift a weight that he is unable to move, has he done any work? Explain.

THE INCLINED PLANE AND ITS USES

Object.—To work with an inclined plane in order to learn how it serves in the performance of our work.

Apparatus.—A board, 2 or 3 ft. long. A toy car or wagon. A cord. A spring balance. Some small weights.

Procedure.—Set up the board as shown in Fig. 210. The high end ought not to be greater than one-fourth the length of the board. Measure

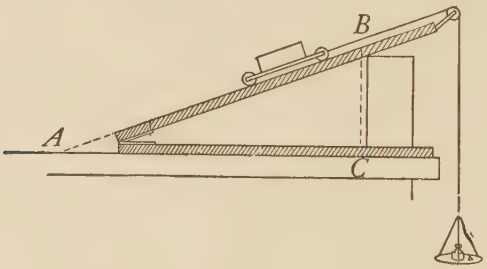


Fig. 210.—An inclined plane. (*From Tower, Smith, Turton and Cope's Physics.*)

the length of the board, or inclined plane, and its height, and record the figures in a table like that shown below. Add enough weight to the wagon until the weight of the wagon and the weights together make a total load of 4 lbs. Record the weight of load in the proper place in the table.

Observations.—Pull the loaded car up the plane and read the force required to pull the car along with an even motion.

Make three trials at different heights and place the numbers in the table as directed above. Calculate the efficiency as follows:

$$\text{Efficiency of inclined plane} = \frac{\text{output}}{\text{input}} \text{ or } \frac{\text{load} \times \text{height}}{\text{force} \times \text{length}}$$

Load =

Trial	Length	Height	Force	Efficiency
1				
2				
3				

Give instances in which you have used an inclined plane.

Give instances in which you have seen an inclined plane in use.

WHEEL AND AXLE

Object.—To make a study of the wheel and axle and to identify its various modifications and applications in and about the home.

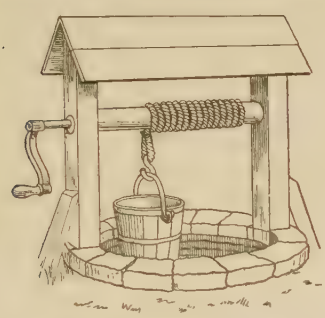


FIG. 211.—Windlass used in hoisting water from a well. (*From Tower, Smith, Turton, and Cope's Physics.*)

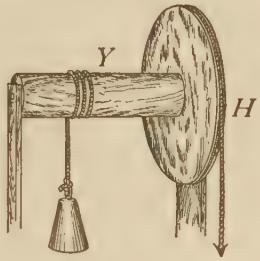


FIG. 212.—The wheel and axle. (*From Tower, Smith, Turton, and Cope's Physics.*)

APPARATUS.—Pencil sharpener, crank type. Dover egg beater Bicycle.

PROCEDURE AND OBSERVATIONS.—Make a study of Fig. 211. Where is the power applied? How is the weight raised? Compare Fig. 212 with Fig. 213. Is the wheel and axle a form of lever in which *r*, the radius of the axle, is the weight arm; and *R*, the radius of the wheel, is the force arm?

Make a detailed study of a pencil sharpener and determine whether or not it is a modified wheel and axle. Where is the force applied? What serves as the resistance or weight? Are the rolling knives a modified axle? Where is the fulcrum?

Make a detailed study of a Dover egg beater, locating the lever arm, the weight arm, and the fulcrum. Which of the cog wheels revolve the greater number of times? Compare the number of cogs in a small wheel with the number in the large wheel. Will this comparison give the number of times the small wheels revolve while the larger wheel revolves once? Are the cog wheels in an egg beater arranged for speed or power? Is an arrangement for speed an advantage or a disadvantage?

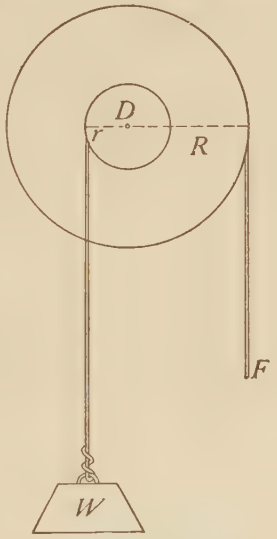


FIG. 213.—The wheel and axle considered as a lever. (*From Tower, Smith, Turton, and Cope's Physics.*)

Make a study of a bicycle. Where is the force applied? Where is the weight or resistance? Where is the fulcrum? How many cogs are there

in the pedal sprocket? How many in the rear sprocket? How many revolutions does the rear sprocket make while the pedal sprocket makes one revolution? How far does the rider travel while the pedal is making one revolution? Is the bicycle a speed machine or a power machine? What is meant by a high geared wheel? In hilly countries should one use a high geared or a low geared wheel? Explain.

WEDGES, CUTTING EDGES, POINTS, SCREWS, AND THEIR RELATION TO THE INCLINED PLANE

Object.—To examine the construction of wedges, cutting edges, points, and screws in order to become acquainted with the conditions that determine their greatest usefulness.

Apparatus.—The students should make a collection of the following articles and display them for class study: an assortment of knives and other cutting edges such as chisels, axes, hatchets, spades, etc.; awls, pins, needles, carpet tacks, thumb tacks, nails, and staples; threaded bolts with nuts, screws with coarse and fine threads, skates with screw clamps, bed clamps, small hand vise, small book presses, and various other articles that employ the principle of the screw.

Procedure and Observations. (*a*) Edges.—Examine several different knife blades. Do you find one edge to be thin and the other thick? Lay the knife blade on the table. Does it in any way resemble the inclined plane? Sharpen your lead pencil with a knife that has a very thin and sharp blade. Slowly move the knife blade and study closely the effects produced as the blade passes through the wood. Repeat the experiment with a thick blade. Try to sharpen the pencil with a table knife. Which of the above blades required the least amount of effort to wedge it through the wood?

Lay an ax or hatchet on the table. Does it resemble an inclined plane? Note the thinness of the cutting edge and the thickness of the head. Are axes and hatchets pressed through the materials which they cut, or are they driven through with forcible strokes? Does inertia aid in driving the ax edge through the wood? Observe the length of the handles on the hatchets and axes. Why are some short while others are long?

Examine other tools and instruments used for cutting. Does the cutting edge in every case resemble a small inclined plane? Examine the teeth in your mouth. Which are used for biting and cutting and which for grinding and chewing?

(*b*) Points.—Examine the points on awls, needles, pins, tacks, nails, staples, etc. Do the sharpened points in any way resemble an inclined plane? Press each point against a soft piece of wood and note the depth to which it may be forced. What is your conclusion about thick points and thin points as regards the amount of force required to wedge them through materials? Which offers the greater mechanical

advantage? Why are small hammers used for driving tacks and larger ones for driving nails?

(*c*) SCREWS.—Select a rectangular piece of writing paper and cut it diagonally into two parts. Wrap one part about your lead pencil as shown in Fig. 214. Observe the spiral formed about the pencil. Partly unwind the paper as shown in Fig. 214. Is the spiral formed by the inclined edge of the paper? Is the spiral about the pencil a spiral incline? Compare the spiral thus made with the spiral grooved on a screw or threaded bolt. What is your conclusion regarding the groove on the surface of a screw? Examine the groove on the screw of a clamp or book press and observe whether it is also a spiral incline.

FIG. 214.—The screw as a spiral inclined plane. (*From Tower, Smith, Turton, and Cope's Physics.*)

Compare a coarse threaded screw with a fine threaded screw. The distance between two threads or grooves is called the *pitch* of the screw.

Take a screw driver and a soft board and decide which is easier to use, a coarse or a fine threaded screw. Which requires the greater number of turns to force it the same distance into the wood? Which corresponds to a high inclined plane and which to a low inclined plane? Does friction help to keep the screw in place? Is resistance useful in this case?

Summarize the uses of wedges by naming the kinds and uses of each, as follows:

Razor edges for shaving.
Axes for felling trees.

Summarize the various kinds of pointed instruments and their uses.

Make a list of articles found in and about the home that involve the principle of the screw. Make a list of all the uses made of screws in your home.

Our Daily Work.—Every day we observe about us great numbers of industrious individuals who are busily engaged in the performance of their daily work. Some are building homes, some are cultivating fields or harvesting crops, some operating trains or boats, some making clothes or preparing meals, some cleaning streets or rushing to extinguish threatening fires, some delivering mail or sending messages, some selling or buying goods, some keeping banks or exchanges, some printing books or papers, some nursing the sick or aiding the poor and distressed; in short, each one is doing some necessary work that in

one way or another contributes to the success and comforts of our daily life.

Machines Save Time and Human Energy.—As we observe these people, we see some who are toiling with their hands and using up great supplies of energy that are stored up in the tissues of their bodies. Others are directing or controlling machines that in one way or another do the work instead of human hands. The man who digs the ditch with a spade is using up the energy stored in his body, while the man who engineers a ditch-digging machine is using energy that is outside of his body—that is, by the means of a steam engine he is able to use the energy that is released from a lump of coal. Here we see two men using machines to help them with their work. The man who makes use of the spade uses a very simple sort of machine, while the other makes use of a very complicated one. Most of the machines that we find about us are for the purpose of saving time and human energy in the performance of necessary work.

Some Simple Machines.—The lever, the inclined plane, and the wedge were probably the first machines used by man. The straight lever formed the handle for his club or ax, while the wedge in the form of a knife or an ax was used in splitting and cutting wood. The inclined plane was early used as a means of getting heavy stones in place on the walls of his rude home or fort. Later the wheel was invented and placed on one end of his lever, and thus the wheelbarrow or two-wheeled cart came into use. When the rope was invented, the wheel with a grooved edge, or pulley, came into use. These simple machines were so effective and useful as mechanical devices that man has continued to use them down through the ages; and when we look about us, we find them in constant service as aids in the performances of our daily labors.

Forces That Oppose Us When We Work.—When we undertake to perform some task, we find that we are opposed or hindered by forces of nature that act against us. For instance, when we wish to move an article or object from one place to another, we find that the article bears down against our hands or bodies with a force which we commonly call weight. This property of *weight* in a body is due to the earth's attraction for the body. Every

particle of matter on earth is attracted and pulled toward the earth's center; and so, whenever we undertake to move an object from one place to another, we find that we must overcome the earth's attraction for it. This attractive force which acts between the earth and each and every particle is known as the force of gravitation.

When objects are so heavy that we cannot lift them, we usually try to drag, or pull, or push them along over the surface of the floor or earth. This is also more or less difficult to do, for the object presses against the surface of the floor or earth, and thus a good deal of *friction* takes place between the two rubbing surfaces. The rougher and more uneven the two rubbing surfaces are, the greater the amount of friction between them. Hence when we wish to move or carry an object, we are opposed by forces that arise from friction or gravitation or both of these forms of resistance.

Again, if we tie a string to a heavy ball or weight and attempt to move it suddenly from its resting position, we may be disappointed by the breaking of the string. Or on the other hand if the ball were in motion, and we should attempt to bring it instantaneously to a state of rest, the string would very likely break, and we should again fail to accomplish our purpose. This condition of affairs has been experienced by the most of us in quite a different way. For example, when we are standing in the aisle of a street car, we are thrown backward and possibly off our feet if the car is started too suddenly; or when we are standing in a swiftly moving car which is suddenly brought to rest, we are thrown forward. If the car in which we are riding is started or brought to rest in a gradual manner with no sudden changes from a state of rest or motion, we do not experience the unpleasant occurrences mentioned above. However, the property of resistance to such changes of state of rest or motion is still present, but overcome so gradually that we do not experience any change as taking place. From the above experience we may conclude that bodies at rest or in motion resist efforts to change their state of rest or motion. This property of a body to remain at rest when at rest, or to remain in motion when in motion, is called *inertia*. Thus far we may say in

summary that there are three sources that give rise to resistance, or opposition to our labors when we undertake to transport objects from place to place, (1) gravitation, (2) friction, and (3) inertia.

How the Forces That Oppose Us May be Made to Serve Us. We can never eliminate the constant action of the force of gravitation. So constant is this force that we make use of it for measuring quantities of matter. To do this we make use of an instrument familiar to most of us, the spring balance, which is so adjusted as to *weigh* quantities of matter in terms of pounds, ounces, kilograms, or grams. The English-speaking countries usually have their balances or scales adjusted so as to record the weight of the object in ounces or pounds, while in the other countries the spring balance records the weight in kilograms or grams. In order to have all the balances record accurately, each nation keeps at the seat of its government a standard pound or kilogram weight. Manufacturers of balances usually have in their possession a tested pound weight or balance, and by means of this standardized weight adjust the scales that they manufacture. All well organized communities have an inspecter of weights and measures whose duty it is to inspect and to examine the balances used in public shops and thus prevent fraud by means of dishonest balances or weights.

FIG. 215.—A spring balance. (*From Tower, Smith, Turton, and Cope's Physics.*)

While the above considerations indicate to us how we make use of the force of gravity to indicate the quantity of matter in a given body by means of the spring balance, this is not the only use that we may make of the spring balance, as the following instances will point out to us. If we wish to weigh out a quantity of butter, or meat, or iron, or any other substance, we add enough of the material until the pointer is opposite the mark numbered one. Such a quantity of material is called a *pound-mass*. If we take hold of the ends of the scale and pull until it registers one pound, we say that we have pulled with a *force of one pound* or more simply a *pound*

of force. The earth's pull on a pound mass is also called a *pound of force.* A spring balance, then, may be used for a double purpose—(1) measuring quantities of matter, and (2), measuring magnitudes of force.

Friction also may serve us in many useful ways. When we walk on a clean piece of sidewalk, we proceed with a feeling of security and think seldom of the danger of slipping or sliding from side to side of the walk. However, when the same sidewalk is covered with a sheet of ice, we find walking upon it an uncertain problem. The leather on the bottom of our shoes does not *take hold* of the icy surface the way it did when we walked on a bare and clean sidewalk. To make such icy walks safe we spread sand over them simply to increase the amount of friction between the bottoms of our shoes and the surface of the ice. Again, automobiles proceed well over dry surfaces and up dry grades or hills; but the moment such surfaces become wet or icy, the wheels slip and revolve without driving the car ahead, and it is then that chains are attached to increase the amount of friction between surfaces of the wheel and the slippery surface. Thus in our daily observations friction serves us in useful ways as frequently as it hinders in the performance of our labors.

The property of inertia in bodies may prove an obstacle and give rise to some very unpleasant experiences and hinder us greatly in our work. The engineer who endeavors to get a heavy train of cars started or stopped must use a great deal of skill to accomplish his task with safety. Yet it is this property of inertia in bodies that serve us at many turns. When we undertake to cross a ditch that is somewhat too wide for us to step across, we go back a distance and run swiftly toward the edge of the ditch before trying to leap across to the other side. Thus the motion acquired before jumping aids in carrying us across. We use hammers with heavy heads when driving large nails. The moving hammer head tends to keep in motion; and thus we are able to drive a nail into a wooden beam with much greater ease and less effort than if we were not so provided. Gas engines, steam engines, meat cutting machines, coffee grinders, and many other similar machines are provided with heavy fly wheels. When such wheels are set in motion, they resist any

sudden effort to stop them, and thus an even motion is obtained while the machine is operated. The above mentioned uses in which the forces of gravitation, friction, and inertia serve us are only a few of a great many. We should be on the constant lookout to see when these forces may be brought into our service or when they hinder us, in order that we may get the greatest benefit from their many applications and occurrences.

How Work Is Measured.—When we lift packages that are on the floor and place them upon a shelf or table, we have done so much work against the force of gravitation. When we raise a one pound package one foot high, we have done a certain amount of work; if we raise one pound two feet high, we have done twice as much work. When we raise a two pound weight three feet, we have done six times as much work as when we lifted the one pound mass through a distance of one foot. From these considerations we are able to see that it is possible to measure work just as easily as it is to weigh out quantities of materials with a spring balance. For when we have lifted a one pound weight one foot high we have done one unit of work. Such a unit of work is called the *foot-pound*, and simply means that a one pound weight has been raised to a height of one foot. When a three pound weight has been raised five feet, fifteen *foot-pounds* of work have been accomplished; or when a ton weight has been raised fifty feet, 100,000 *foot-pounds* of work are the result. When we climb a stair we are raising the weight of our bodies from the floor below to the floor above, and the exact amount of work that was required is actually calculated by multiplying the weight of our bodies by the distance between the two floors.

$$\text{Work} = \text{force} \times \text{distance},$$

or

$$\text{Foot-pounds of work} = \text{pounds} \times \text{feet}.$$

From the above considerations it becomes at once necessary for us to be sure that we understand each other when we talk about *work*. Work is done only when a force is used to move an object through a distance. When a workman shovels coal into a wagon, or a housewife sweeps the floor, or an engine drives a pump while pumping water, work is being done—forces are

operating through distances. Now a man who attempts to lift a piano which he is unable to move does no work. The table or desk which supports our books and other working instruments does no work, for the reason that no forces have traveled through a distance. Any force that is exerted in an attempt to move an object which does not move is *wasted effort.*

Again the amount of work that we do when we ascend a flight of stairs is exactly equal to the amount of work performed when we descend the stairs. For the same force, the weight of our body, has traveled the same distance in each case.

Work ascending stairs = weight of body × height between floors.

Work descending stairs = weight of body × height between floors.

Work ascending stairs = work descending stairs.

The above facts may be summarized into the following statement. *The amount of work done is always equal to the force multiplied by the distance through which it travels.*

The Lever and Its Uses.—When we desire to move a heavy object like a rock or a log from one position to another, we are quite in the habit of getting a stout stick or an iron bar and using it as a pry in order to force the heavy object into its new position. When doing this sort of thing, we thrust one end of the stick under the object and then lift up or press down on the long handle that extends out toward us, and in this manner we are able to move the heavy object a short distance. By doing this sort of act over and over we are able to move a heavy weight to considerable distances.

FIG. 216.—By means of a lever a heavy object is easily moved. (*From Tower, Smith, Turton, and Cope's Physics.*)

When using a lever we soon learn that it is necessary to have a firm resting place, which is to serve the lever as a support, as shown in Fig. 216. When we press down on the long end of this lever, the stone moves upward while the lever is turning on its resting place. Such a support is always necessary for a lever and is called the *fulcrum.* Hence when we use a lever three things are essential, (1) a weight, (2) a fulcrum, and (3) a force.

These three things may be arranged on the lever in three ways, as shown in the Fig. 217 (*a*), (*b*), and (*c*). Thus we see we have three classes of levers. The first class always has the fulcrum, *O*, between the acting force, *F*, and the weight, *W*. The second class always has the weight, *W*, between the fulcrum, *O*, and the force, *F*. The third class always has the force, *F*, between the fulcrum, *O*, and the weight, *W*.

The distance from the force to the fulcrum is always called the force arm, while the distance from the weight to the fulcrum is always known as the weight arm. When the force arm is longer than the weight arm, the force is less than the weight.

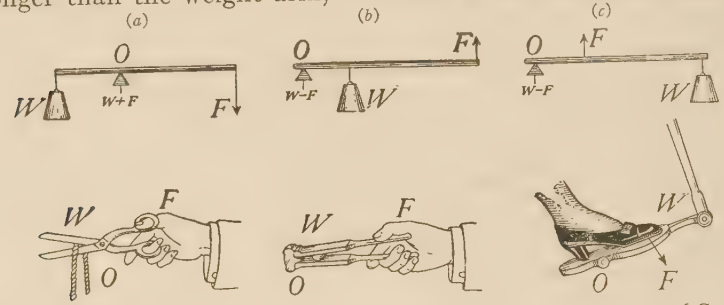


FIG. 217.—The three classes of levers. (*From Tower, Smith, Turton, and Cope's Physics.*)

Indeed when the force arm is many times longer than the weight arm, a very small force is capable of moving a very large weight. However, when we use long force arms and short weight arms, we shall always find that the distance that we actually move the weight is very small when compared to the distance which the force was moved. To be exact, when the force arm is three feet long and the weight arm is one foot long, a one pound force will have to move through a distance of three feet to raise a three pound weight one foot. In short, 1 pound of force acting through a distance of 3 feet raises a 3 pound weight through a distance of 1 foot, and thus the work done equals the work received; that is,

Force × distance force traveled = weight × distance weight traveled

or, work spent = work received

Efficiency of Machines.—From the above we are led to believe that we are able to get out of a machine as much work as we

put into it. However, this can never be the case, for in every machine some work is always wasted in overcoming friction that arises from various sources. Hence when we use machines we shall find that the amount of work spent is always greater than the amount received from the machines, and for this reason the following statement is better than the one given above.

Work spent = useful work + work wasted in friction.

The usefulness of machines largely depends upon the amount of work that is returned to us in the form of useful work. If a large part of the work put into a machine is used to overcome friction, the efficiency of the machine is very low, and indeed, it may be worse than having no machine at all. This is noticeable when we ride a poor bicycle after having ridden a very good one. The bicycle that is not kept in good condition may have sand and dirt about the ball bearings and other rubbing parts, and thus a good deal of unnecessary work is required to overcome the friction that exists. The bicycle that is kept in good condition lessens the amount of work necessary to overcome friction. Hence a bicycle kept in good condition is more efficient than the one in poor condition. Since it is impossible to make a frictionless bicycle or any other kind of frictionless machine, it is impossible to have a machine which is 100% efficient—that is, a machine that will give as much work as we put into it. To find the efficiency of a machine we simply compare the work received from it with the amount put into it.

$$\frac{\text{Work received from machine}}{\text{Work put into machine}} = \text{efficiency of the machine, or}$$

$$\frac{\text{Foot-pounds received from machine}}{\text{Foot-pounds put into machine}} = \text{efficiency of the machine.}$$

This statement applies to any and all machines, and is in daily use among engineers and mechanics who wish to know exactly the efficiency of the machines that they use in the performance of their daily tasks.

The Wheel and Axle.—By means of levers we are able to raise weights short distances; but when we wish to raise weights to great heights, the lever is not convenient and practical.

For this reason the wheel and axle was invented and brought into use. In this machine Fig. 212, the power is applied to the circumference of a wheel, H, that is fixed to an axle to which the weight is attached by means of a rope. When the wheel is turned the rope is wound about the axle, and thus the load is raised. The larger the wheel, the less the force required to raise a given weight. In this respect the wheel and axle may be considered as a lever, Fig. 213, in which the radius, R, of the wheel is the power arm, and the radius, r, of the axle is

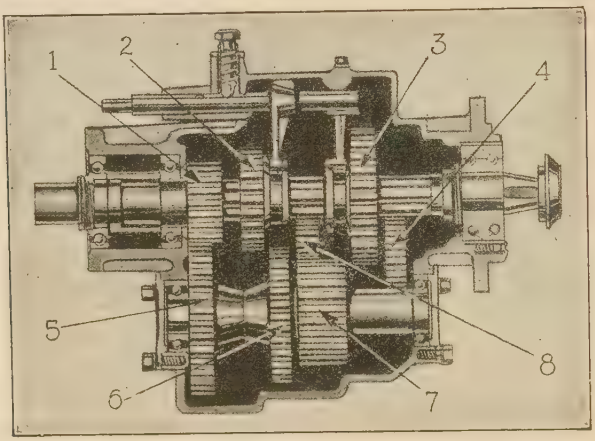


FIG. 218.—View of transmission gears in an automobile. (1) Drive gear; (2) high and intermediate gear; (3) low and reverse gear; (4), (8), reverse idler gears; (5), (6), (7) countershaft gears. (*Courtesy of the Automobile Journal.*)

the weight arm. Hence the mechanical advantage of a wheel and axle is simply the number of times that the radius of the wheel is greater than the radius of the axle.

The wheel and axle is one of the most important and useful machines, and it is found in many modified forms in our homes and the community about us. The windlass, Fig. 211, is a modified form in which the handle serves the purpose of the wheel. The egg beater with its cog wheels for turning the dashers is a modified wheel and axle in which cogs do away with the use of ropes. The mechanical advantage of the egg beater may be found by dividing the number of cogs in the large wheel by the number of cogs in one of the small wheels. The transmission gears in an automobile, Fig. 218, are also modified

forms of the wheel and axle. In these modified forms of the wheel and axle we find arrangements of wheels and shafts for the purpose of increasing or decreasing the speed of various parts of the machine. These arrangements allow for certain shifting of the gears so well known in automobile circles by such expressions as "shifting to high," "to low," "to neutral," and "to reverse." When we shift "to low" the power from the engine is directed to the circumference of a larger gear wheel, which allows the engine to work on a longer lever arm. Examine the meat grinder, hand coffee mill, and various other machines in the home and determine whether such machines contain a modified form of the wheel and axle.

The Pulley.—Perhaps one of the simplest devices for moving and raising weights to considerable heights or distances is an arrangement of pulleys and ropes. When working with a single fixed pulley, Fig. 219, we find that there is no mechanical advantage, for the force required to raise the load is equal to the sum of the load lifted and the friction in the pulley. However, there is one advantage in the use of the fixed pulley, and that is the direction in which the force operates while lifting the weight. When raising weights to the top of a wall or a building the workman finds it very disadvantageous if he has to go to the top of the wall and pull upwards. To avoid this disadvantage the rope is run over a fixed pulley, which enables the workman to pull downward with the weight of his body.

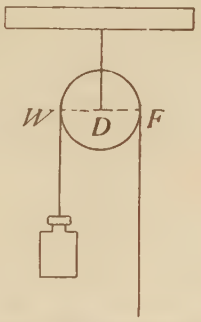


FIG. 219.—The single fixed pulley. (*From Tower, Smith, Turton, and Cope's Physics.*)

If, when a fixed pulley is used, the force operates through a distance of ten feet, the weight is also raised ten feet; but as was stated the acting force is greater than the weight on account of friction. Thus again we see that the amount of work spent on a machine is greater than that received from it, yet in spite of this fact the machine is a labor saving device. For if the workman had to carry loads of stone and brick to the top of the wall, he would on each and every trip have to carry the weight of his body up and down a distance equal to the height of the wall.

Since the weight of his body would be about twice that of the load he would carry, and since he would carry his body twice

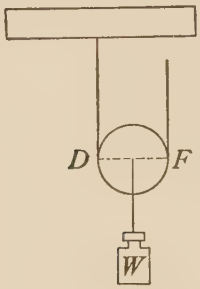


FIG. 220.—The movable pulley. (*From Tower, Smith, Turton and Cope's Physics.*)

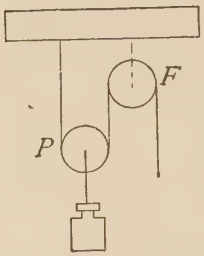


FIG. 221.—Single movable pulley. (*From Tower, Smith, Turton and Cope's Physics.*)

as far (up and down) as he carried the load, we can readily see that the useless labor would be nearly four times that of the useful labor. The efficiency of the fixed pulley is seldom lower than 50%; hence its service to man.

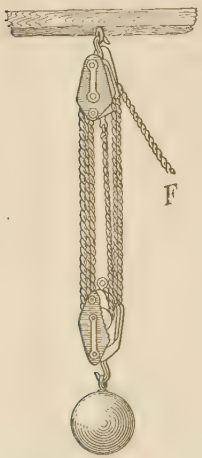


FIG. 222.—Block and tackle. (*From Tower, Smith, Turton, and Cope's Physics.*)

When the rope and pulley are arranged as shown in Fig. 220, we have what is called a movable pulley. The weight is attached to the pulley through which passes a rope one end of which is attached to a support. When the free end of the rope is drawn upon, the pulley and weight are raised one half the distance that the acting force travels, and, if we neglect friction, the force is only one half of the weight.

A fixed pulley and a movable pulley may be arranged as shown in Fig. 221, and thus the advantage of each may be combined in a single operation. Here two ropes again support the movable pulley and weight, and hence only one half the weight is supported by either rope. When we pull on the free end of the rope, we are only pulling with a force that is half as

great as the load plus the friction in the bearings of the pulleys and the stiffness of the rope. However, the force travels two feet in order to raise the weight a distance of one foot.

As shown in Fig. 222, we may have several pulleys in a frame or block; and when two such blocks are threaded with a rope, we have an arrangement known as a block and tackle. By this arrangement a load several times larger than the effort can be raised. In Fig. 222 six ropes are shown as supporting the weight. If a force of 100 lbs. acts at F, each strand of rope will have a force of 100 lbs. acting on it, and hence the total downward pull on all six ropes is 6×100 lbs. or a total of 600 lbs., or we may write:

The force $\times$ the number of ropes supporting the weight = the weight, or

$$F \times N = W$$

This statement does not take into account the friction in such an arrangement of pulleys and rope. In this instance the force, F, would have to move six feet in order to raise the weight one foot; and if we again neglect the friction, we are able to write the following equations:

$$100 \text{ lbs.} \times 6 \text{ ft.} = 600 \text{ lbs.} \times 1 \text{ ft., or}$$
$$600 \text{ foot-pounds} = 600 \text{ foot-pounds, or}$$
$$\text{work spent} = \text{work received.}$$

If we perform the experiment suggested above with such a block and tackle, we may find that in order to raise a load of 600 lbs. it may be actually necessary to pull on the free end of the rope with a force of perhaps 200 lbs. The extra 100 lbs. of force is required to overcome the friction in block and tackle when under a load of 600 lbs. In this case we have 200 lbs. passing through 6 ft. while raising a load of 600 lbs. through a distance of 1 ft. From these figures we can calculate the efficiency of the machine from the principles mentioned in the discussion of the lever.

$$\frac{\text{work received}}{\text{work spent}} = \text{efficiency of machine}$$

$$\frac{600 \text{ lbs.} \times 1 \text{ ft.}}{200 \text{ lbs.} \times 6 \text{ ft.}} = \frac{600 \text{ ft-lbs.}}{1200 \text{ ft-lbs.}} = .50 \text{ or } 50\% \text{ efficiency}$$

In the simple lever there is very little friction as the lever turns upon its support or fulcrum, and the efficiency is very nearly 100%; but as the machines grow more complicated, there is likely to be a greater rubbing of moving surfaces and thus greater amounts of friction. The greater the friction is, the more expensive it is to operate the machine. To cut down expense due to friction between the several parts of machinery, oils and grease are used to lubricate the rubbing surfaces. Graphite, a form of carbon, is also largely used to prevent friction. These lubricants not only lessen the friction between the rubbing parts, but also lessen the wear between the rubbing surfaces. Many costly machines are ruined daily by workmen who neglect to lubricate them properly. Lubricators not only save the wear and tear on the machinery, but lessen the amount of wasted work and raise the efficiency of the machine.

The Inclined Plane, Wedge, and Screw.—Of the six simple machines the lever is perhaps the most employed and most useful. We find the lever fashioned by nature into arms, legs, wings, fins, paws, and necks in the various types of animals for the purpose of producing countless kinds of motion for the performance of bodily work. The wheel and axle does not occur in nature, but, as mentioned above, it is used in many modified ways in man's machines for the accomplishment of work outside of his body. However, it is quite possible that some of us may live a long life and never make use of a block and tackle in the performance of a single task. In the case of the inclined plane, the wedge, and the screw we find them constantly serving us in many ways. Every street or road which is not level is an example of an inclined plane. Every set of steps that leads into a home, or flight of stairs within the home or other building, is an inclined plane. Every knife, ax, sword, and every edge used for cutting or splitting materials is an example of a wedge. Points on needles, awls, tacks, staples, and nails are also applications of the wedge in the arts of man. If we examine one of the common types of water faucets, we shall find that the screw is employed as an aid to "turn on" or to "turn off" the water supply. When we adjust a common pair of opera glasses, or twist a clothes hook into the closet

wall, or fasten a hinge or lock to a door, or tighten a pair of skates to our shoes, the screw comes into use in an exceedingly serviceable manner.

The inclined plane, the wedge, and the screw are generally regarded as three types of machines, but after a little consideration we shall find them all to be modified forms of the inclined plane. The wedge is simply an inclined plane used as a cutting edge, while the screw is nothing more nor less than a spiral inclined plane, Fig. 214. Everyday experiences teach us that the steeper the inclined plane, the greater the pull or effort required to haul a load up the grade. When we roll a barrel or cask up an inclined plane for the purpose of loading the barrel or cask onto a wagon, we find that the force required to roll the barrel is less than the weight of the barrel. In such a case the longer the plank is, the smaller will be the required force to roll the barrel. However, the law of work for machines applies here just as well as for any other machine. The force that rolled the barrel passed through a distance equal to the length of the plank in order to raise the weight of the barrel to the height of the wagon or plane. Therefore, aside from friction,

$$\text{force} \times \text{length of plane} = \text{weight} \times \text{height of plane},$$

or

$$f \times l = w \times h$$

Projects

1. To compare tin or metal shears with ordinary scissors and to account for their likenesses and differences of construction (Fig. 223).

2. To determine which of two methods requires the greater amount of work: (*a*) to drag a 10 lb. body a space of 10 ft. or (*b*) to lift the 10 lb. body up three feet and then carry it 10 ft. and set it down in its new position.

3. To discover why it is better to pound the end of the handle rather than the head when setting a hammer head on its handle. Demonstrate with materials.

4. To test the various kinds of balances or scales found in the home with those found in the school laboratory and with those found in the department of weights and measures of the city.

5. To collect and exhibit in display bottles, the various kinds of lubricating oils and lubricating agents, and to read a paper setting forth the uses of each variety. (Write to oil companies and to similar agencies for literature and samples.)

6. To collect and display various kinds of ball and roller bearings and to set forth the advantages arising from their uses.

7. To set forth in a written paper the impossibilities versus the possibilities of inventing a perpetual motion machine.

8. To study the transmission gears in an automobile and to explain by means of pictures and advertisers' charts what is meant by "in high," "in low," "in neutral," and "in reverse."

9. To locate and set forth the uses of each class of levers as exemplified in the human body.

10. To design an arrangement of simple machines for the purpose of hauling a heavy boat or launch ashore for repairs or storage.

11. To make a study of some machine in the home for the purpose of determining whether it operates on the principle of the lever, the wheel and axle, the pulley, the inclined plane, the wedge, or the screw, or combinations of these simple machines.

12. To construct from "Mechano" or "Erector" parts a model of a derrick or crane in which the lever, the wheel and axle, and pulley are all employed, and to demonstrate the operating principles of such a model to the class.

FIG. 223.—(*a*) Scissors; (*b*) tinner's shears. (*From Tower, Smith, Turton, and Cope's Physics.*)

Problems

1. A hod carrier weighing 175 lbs. carries 75 lbs. of brick up a ladder of 25 ft. How much work does he do in all? How much of his work is useful?

2. It requires a force of 90 lbs. to roll a 200 lb. barrel up an inclined plane 10 ft. long to a height of 4 ft. Determine the efficiency of such an inclined plane.

3. Make a drawing setting forth the arrangement of pulleys and ropes necessary to raise 100 lbs. with a force of 25 lbs., neglecting friction.

Topics

1. Give a brief account of the life of Archimedes and his mechanical inventions.

2. Give an account of Elias Howe and the sewing machine.

3. To read parts of the following books and to report on one or more topics of interest found therein:

(*a*) "Great Inventions and Discoveries," W. D. Piercy, C. E. Merril Co.

(*b*) "Stories of Useful Inventions," S. E. Forman, Century Co.

(*c*) "Great Inventions and Their Inventors," Bachman, American Book Co.

(*d*) "Stories of Inventors," Doubleday, Doubleday Page and Co.

(*e*) "The Boy Mechanics," Chicago Popular Mechanics Co.

(*f*) Report books and articles on machines, inventions, and inventors not listed here.

4. To search the recent numbers of the Scientific American, or similar magazines or journals, for reports on inventions or improvements in household machines, and to report the findings to the class.

CHAPTER XX

HOW MAN PUTS THE FORCES OF NATURE TO WORK

Object.—To make a study of the sources of energy and man's methods of harnessing these natural forces to his labor saving devices.

Forces Set to Work.—Whenever man has discovered a new source of energy, he has found it necessary to create new tools and machinery with which to harness his new power before he could make it work for him. He tamed the ox and the horse; but before either could be used to plow the fields or to grind his grains, yokes, harnesses, plows, and mills had to be made. In such cases it is difficult to decide which required greater intelligence on the part of man: to tame the ox and the horse or to design and make his yokes, harnesses, plows, and mills. Likewise before he could use the wind to drive his boat, he must make a sail and set up a mast. Before he was able to use the power of running water or a waterfall, he must invent a water wheel with which to harness this kind of power.

It took man a long time to use heat as his helper in his work of lifting and carrying loads, and thus to save human strength. Heat probably never would have been harnessed and set to work by man, had he not found such a fuel as coal, which provided him with a hot fire that released great quantities of heat energy. But before heat could be used as such a source of power, a harness for it had to be invented. The first harness applied to the heat of fires was the steam boiler connected to the steam engine. The steam engine proved to be an effective harness for the new source of power. Man made new and better machines for it to operate, and in a short space of time large manufacturing centers with great engines and powerful machinery grew up in the place of small ones where human hands had done most of the heavy toil.

Man no longer waits on the ox or the wind to carry him and his wares from place to place, but instead he is carried quickly

over land or sea in swift airplanes, rapidly moving trains, or gigantic steam ships. Electricity, coursing over wires, lights his home and city, pulls his street cars, drives the many labor saving devices of his factories and mills, and carries his messages to or brings information from the many corners of the earth. Since the forces occurring in nature serve us every day, it is quite necessary that we become well informed concerning them.

SOURCES OF ENERGY AND MACHINES (HOME PREPARATION)

Object.—To make a survey of the various machines and the sources and forms of energy that drive them in the performance of work.

PROCEDURE.—Observe machines in operation and endeavor to discover the nature of the source of power and the purpose of the machine. Record your observations and conclusions in the form of a table as indicated below. Record, also, those machines with which you are already familiar.

Machine	Source or form of energy	Labor performed
Broom	Human.	Sweeping floors.
Concrete mixer	Combustion of gasoline in a gas engine.	Mixing concrete for building pavements.
Vacuum sweeper	Electricity.	Cleaning rugs, etc.

WIND AND WATER MOTORS (HOME PREPARATION)

Object.—To make a study of machines that derive their power from the movements of wind and water.

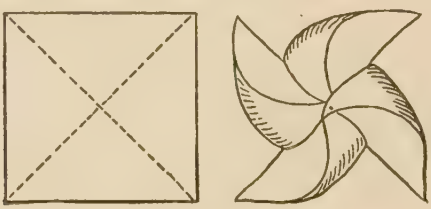


FIG. 224.—Paper wind wheel.

APPARATUS.—Scissors. Ruler. Pencil.

MATERIALS.—Manilla paper or stencil paper. Pins.

PROCEDURE AND OBSERVATIONS.—Cut a square, 9 inches × 9 inches, from the manilla paper. Draw the diagonals. On the diagonal mark off

4½ inches from each corner. Cutting along the diagonals cut to the mark of 4½ inches. From the paper thus prepared make a common wind wheel.

Hold the wind wheel in various positions before the wind. Discover the position in which the wheel rotates at the greatest speed.

Study Fig. 225. Observe the arrangement of the several fans in the wind wheel. What is the purpose of the vane? Where are the windmills of great use? What kinds of work are accomplished by the use ofwindmills?

What is the purpose of sails on boats?

How are they held before the wind? How is it possible to cross a lake in a sail boat when the wind blows from the opposite shore? Explain.

In what other ways is wind made to work?

Clip off the points of the paper wind wheel and hold one edge of it under a stream of water. Vary the position of the wheel under the stream so as to obtain the best results.

Recall the work on water wheels and turbines as set forth in Chapter XV. Which type was set forth as the more efficient? Give the uses that are made of water wheels and water turbines.

Obtain a small water motor usually found in laboratories and make a study of its construction. These motors usually employ a wheel of the Pelton type.

FIG. 225.—A windmill. *(From Tower, Smith, Turton, and Cope's Physics.)*

STEAM AND THE STEAM ENGINE

Object.—To make a study of the conditions under which steam is made to do work.

APPARATUS.—Flask. Beaker. Glass tubing. Bunsen burner. One or more working models of a steam engine. One or more toy steam engines loaned to the class by pupils or friends.

MATERIALS.—Copper or aluminum foil. Cork. Needle. Twelve inches of #18 wire.

PROCEDURE AND OBSERVATION.—(*a*) Demonstration. 1. Place some water in the flask and arrange the apparatus as indicated in Fig. 226. The upright tube may be 10 or 12 inches above the top of the flask. Support all apparatus with ring stands and clamps.

2. When everything is properly adjusted, *carefully heat the water* in the flask. Observe closely all that takes place.

3. Why does the water rise in the tube? Care must be taken to see that the steam is not generated too rapidly. Why?

4. Is water raised from one level to a higher level? Has work been done? Is the presence of heat essential? Is heat a form of energy?

5. From the copper foil construct a fan wheel. Cut the cork squarely into halves. Center the wheel between the two halves. Through all pass a long sewing needle which serves as an axle. Mount the wheel as indicated in Fig. 227. Provide a safety tube to serve as a safety valve.

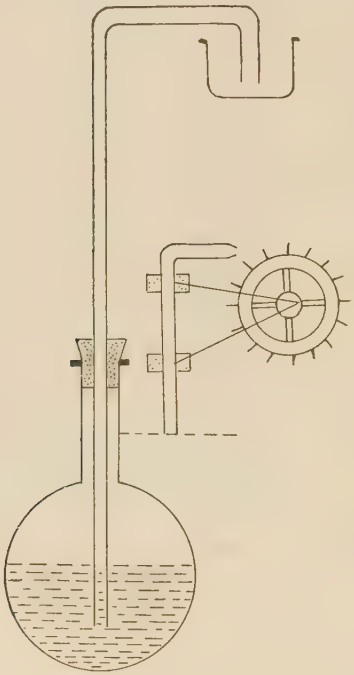


FIG. 226.—Two methods of putting steam to work.

FIG. 227.—Arrangement of apparatus for demonstrating the steam turbine.

Boil the water in the flask, and adjust the flame so as to give a steady flow of steam. *Caution—exercise great care when working with steam, hot water, and flames.*

Does the rotating wheel suggest a means for using heat energy for operating machinery? Compare this means of applying steam to that shown in Fig. 228. In what way are they similar? Is this method used to any extent for transforming heat energy into mechanical energy? Give instances.

(*b*) Laboratory study.

6. Examine a working model of a steam engine. Operate it and discover its working principle.

7. Examine a toy model of a steam engine and discover its operating principles. Locate the safety valve. Is it in working order? If so, arrange to put the toy model into actual operation.

8. Write a brief report that sets forth the various ways of putting steam to work—changing heat energy into mechanical energy. State some of the uses made of steam engines.

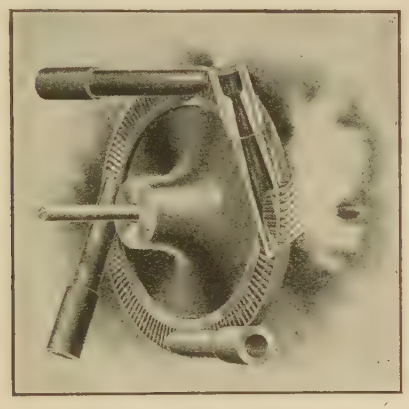


FIG. 228.—De Laval's steam turbine. (*From Tower, Smith, Turton, and Cope's Physics.*)

GAS AND GAS ENGINES

Object.—To make a study of the conditions whereby it is possible to make use of the energy stored away in gaseous fuels.

APPARATUS.—Model hot air engine. Small gas engine as used on bicycles or in similar light work, or on motor cycles or automobiles.

MATERIALS.—Two wide mouth bottles. Cover glasses. Coffee pot with hinged cover. Pan. Rubber tubing. Source of illuminating gas.

PROCEDURE AND OBSERVATIONS.—1. Fill the pan with water. Fill one bottle half full with water and invert in the pan of water. Fill the other full of water and invert. Allow gas to bubble up into the bottles until all the water has been expelled. Place a glass cover over the mouth of each bottle, remove and place in an upright position on the table. One bottle contains a mixture of air and gas; the other contains pure gas. Bring a lighted match to the uncovered mouth of each. Which gives the better explosion? Why? Repeat the experiment with varying portions of air and gas and determine the best mixture.

2. At about an inch from the bottom make a hole, ¼ inch, in the side of a coffee pot. Make another hole about half way up the side. Stick one end of the rubber tube through the lower hole and allow enough gas

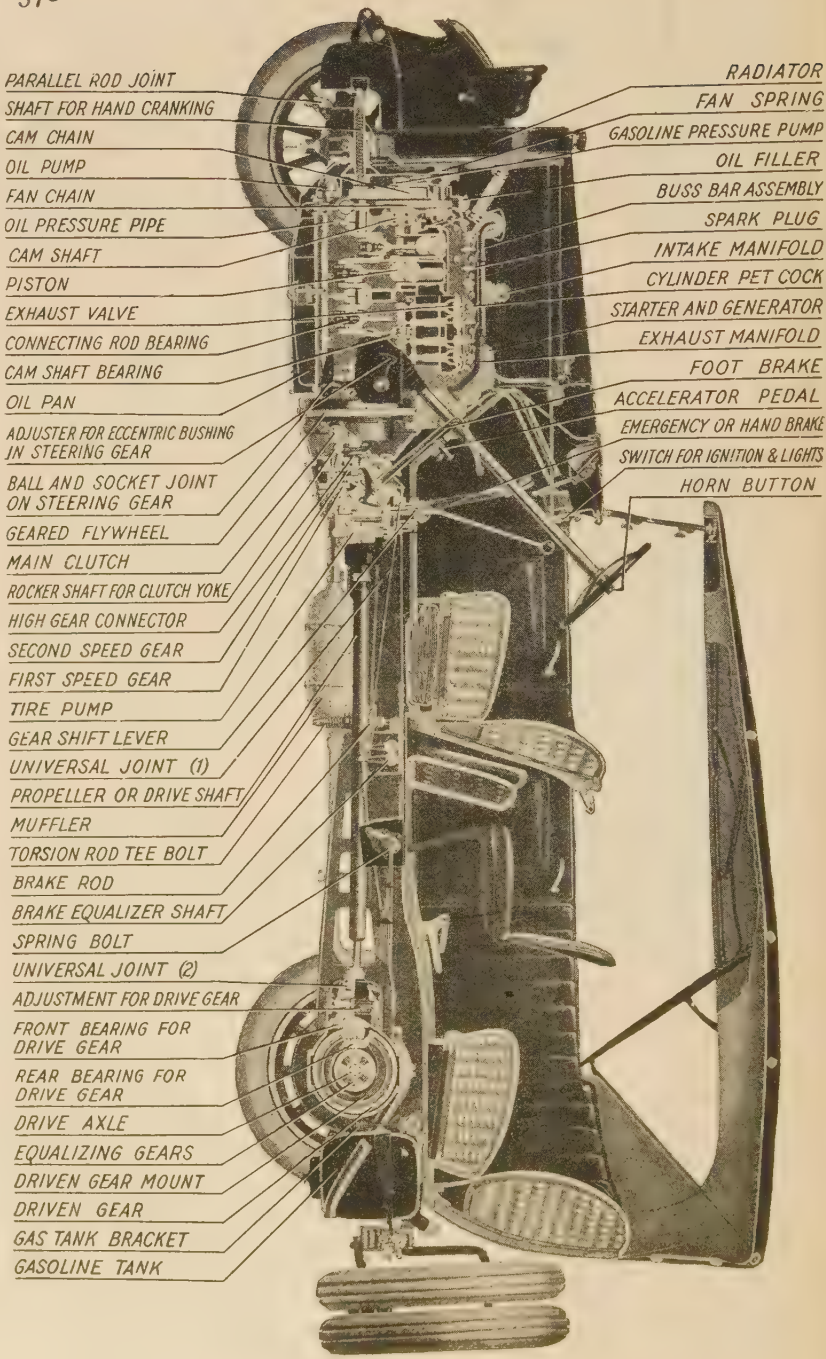


FIG. 229.—Gas engine installed in the chassis of an automobile. (*Courtesy of the Cadillac Motor Car Company, Detroit, Mich.*)

to enter to make a mixture similar to that which was found to be the best in (1). Bring a lighted match to the upper hole and introduce the flame into the pot. Is the explosion sufficient to lift the lid? Repeat with various mixtures. Is there a source of energy in exploding mixtures of combustible gas and air (oxygen)?

3. Examine a working model of a hot air engine. Find the cylinder or explosion chamber. Does a *piston rod* communicate with a *piston head* and crank shaft? Move the wheels and observe the "to and fro" motion given to the piston rod. Make arrangements actually to operate the model with illuminating gas.

DEMONSTRATION.—4. Have one or more students conversant with gas engines demonstrate a small working model gas engine to groups of two or three students. A chart showing the four cycles should be used in the demonstration, Fig. 247. The carburetor, spark plug, valves, cooling devices, crank shaft, piston rod, piston head, and every other detail should be taken up and pointed out.

5. If convenient the study should be continued with gas engines found in automobiles. Students who drive cars and are informed may demonstrate and point out essentials to small groups. Show how the engine is controlled from the steering wheel. Point out and explain in a simple way the purpose of the modified carburetor; the ignition system; the cooling system; the self starting and lighting systems; the transmission; and other related details (as shown in Fig. 229).

6. In a written report compare and contrast the gas engine with the steam engine.

MAGNETS

Object.—To make a study of magnets.

APPARATUS.—Two Bar magnets. Compass.

MATERIALS.—Iron filings. Glass square. Wire nails. Needle. Soft iron rod, 6 inches × ¼. Square of paper 8 inches × 10 inches.

PROCEDURE AND OBSERVATION.—1. Suspend the bar magnet by a string so that it can turn freely. What position does it take when it comes to rest? The ends of the magnet are called the *poles*. The one which points to the north is called the *north pole;* the end pointing toward the south, the *south pole*. Label the north-seeking end with an N; the south-seeking end, S. Repeat the work with a second magnet and properly label its ends N and S.

2. Suspend one of the magnets as before and bring the north pole of the other near to the north pole of the first, Fig. 230. Bring the south poles near to each other. What takes place when an N-pole approaches an N-pole? When a S-pole approaches a S-pole? Do like poles repel or attract each other? Bring an N-pole near to a S-pole. What happens? Do unlike poles attract or repel each other? Make laws that state when attraction and repulsion take place between the poles of a magnet.

Does the experiment show that there is a region surrounding a magnet in which there is some kind of force acting? This region about the magnet is called the *magnetic field.*

3. Lay the magnet on the table and under a piece of paper or cardboard. Sprinkle iron filings through a cloth onto the surface of the cardboard. Tap the cardboard paper. Do you observe the filings arranging themselves into definite lines each time that the cardboard is gently tapped? If so, the filings show you the *magnetic lines of force* that make up the magnetic field about the magnet. Do the filings show the lines of force to be curved as though passing from one end back to the other? Repeat with the second magnet. Is there a *magnetic field* about this magnet similar to the one about the first? Compare your work with that shown in Fig. 231.

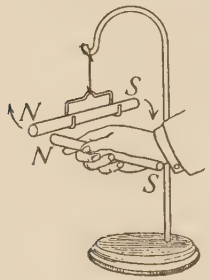


FIG. 230.—Like poles of two magnets repel. (*From Tower, Smith, Turton, and Cope's Physics.*)

4. Place the magnets in a line on the table so that the N-poles are opposite to each other and separated about 1 inch from each other. Cover with a paper and sprinkle the surface with iron filings. Tap the paper or cardboard. Are there signs of repulsion or attraction between the magnetic lines of force that run out from the poles of the magnet? Compare results with Fig. 232.

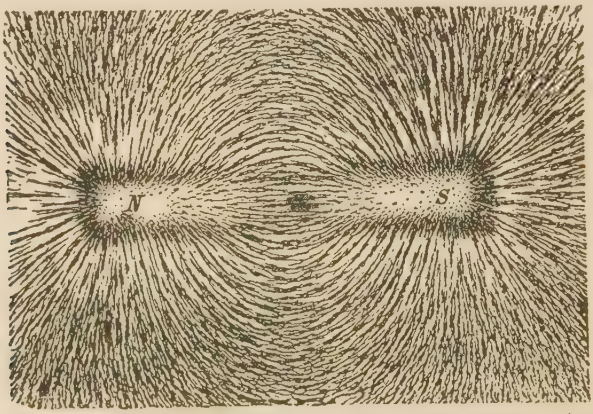


FIG. 231.—Iron filings show magnetic field about a bar magnet. (*From Tower, Smith, Turton, and Cope's Physics.*)

5. Repeat (4) with an N-pole opposite a S-pole. Is there an attraction or a repulsion? See Fig 233. Compare your conclusion with the laws that you made in (1).

6. Does a magnetic field reveal itself to your senses; that is, as you view a magnet are you able *to see* a magnetic field and its magnetic lines

of force? Can you smell them? Can you hear them? Taste them? Feel them? Light is a form of energy which we can see. Heat is a form of energy which we can feel. But magnetic lines of force make no appeal to any of our senses. Why, then, were iron filings used in (3), (4), and (5)?

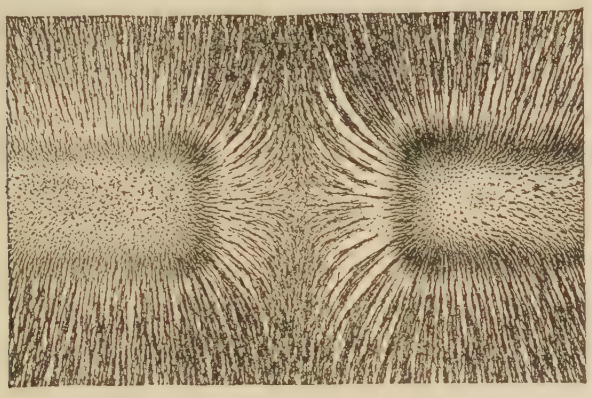


FIG. 232.—Magnetic field between like poles of two magnets showing repulsion. (*From Tower, Smith, Turton, and Cope's Physics.*)

7. Examine a compass. No iron or magnets should be near at hand during the examination. Why? Does the compass behave like a suspended magnet? Observe which end is the N-pole. Bring an N-pole of a magnet near to the N-pole of the compass. Move the N-pole of the bar

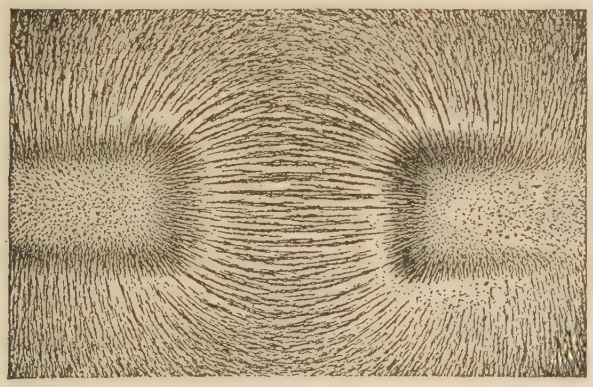


FIG. 233.—Magnetic field between unlike poles of two magnets showing attraction. (*From Tower, Smith, Turton, and Cope's Physics.*)

to right and to left. Same with S-pole of magnet. Does the magnetic field about the magnet disturb the compass at a distance of 6 inches? One foot? Two feet? Three feet? Is the earth itself a huge magnet? Does your answer explain why a compass needle generally points in a north and south direction?

8. Stick one end of a bar magnet into some iron filings, and withdraw the magnet. Wipe off the end and repeat with the other end. Repeat using the soft iron bar. How does the soft iron bar differ from the magnet? Are there any differences in the behavior toward the compass of a bar magnet and the soft iron bar? Try it and observe the differences.

9. Place one end of the magnet on one end of the soft iron rod and lower the other end of the rod into some iron filings and then slowly raise the rod and bar. Are there any filings on the end of the rod? Remove the

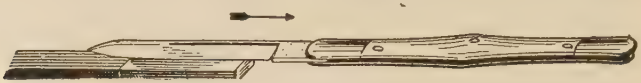


FIG. 234.—Making an artificial magnet out of a knife blade.

bar from the end of the rod. Do the filings fall from the end of the rod? Repeat several times. Change ends to the bar and repeat. When does the soft iron rod act like a magnet? When does it not?

10. Draw a knife blade several times over one of the poles of a magnet. Always draw the knife in one direction, do not draw forth and then back. Test the knife blade with iron filings. Is it a magnet? Blades of knives are made of hard and tempered steel. If you wanted to make a permanent magnet would you use a hard or soft steel?

ELECTROMAGNETS

Object.—To learn how to make an electromagnet.

APPARATUS.—Compass. One dry cell or door bell type of cell.

MATERIALS.—2 yards double cotton-covered #18 copper wire. Iron filings. $6'' \times \frac{1}{4}$ soft iron rod.

PROCEDURE AND OBSERVATIONS.—Caution. Do not use the battery for more than 3–4 seconds in any trial.

1. Place the compass needle in the center of the table. While one pupil holds the wire in a north and south direction directly above a compass

FIG. 235.—Method of holding wire directly over compass needle.

needle, Fig. 235, another may touch the bare ends of the wire to the binding posts of a battery. What does the needle do each time the wires are touched to the battery? Each time the wires are taken away from the battery? Place the wire under the compass. The wire and needle must be parallel before the wires are applied to the battery terminals. Observe the action of the needle when the current flows through the wire.

This work was done to show that whenever a current of electricity flows through a wire there is a magnetic field about the wire. When the current stops flowing there are no magnetic lines of force about the wire.

2. Wind the wire 12 times about the soft iron bar (Fig. 236). While the current is passing, dip one end of the bar into some iron filings and withdraw. Is the rod a magnet so long as the current is flowing? Is it a magnet when the current is not flowing? Using the compass determine which is the N-pole and which is the S-pole. Change the direction of the flow of the current through the wire by touching the wires to different terminals. This magnet is called an electro magnet. Why?

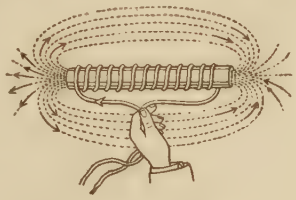


FIG. 236.—How to make an electromagnet. (*From Tower, Smith, Turton, and Cope's Physics.*)

3. Wind 24 turns about the rod and repeat the experiment. Is the electromagnet stronger with 12 turns or 24 turns?

MACHINES THAT USE ELECTROMAGNETS

Object.—To study some machines in which the electromagnet is used to do work.

APPARATUS.—Electric bell. Push button or simple strap key. Telegraph key and sounder. Toy motor. Two cells.

MATERIALS.—#18 copper wire.

PROCEDURE AND OBSERVATION.—1. Examine the details in the construction of an electric bell; of a push button or key. Connect the cells,

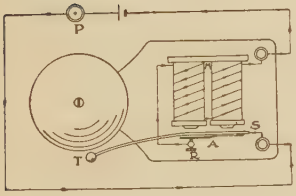


FIG. 237.—An electric bell in a series circuit with battery and push button. (*From Tower, Smith, Turton, and Cope's Physics.*)

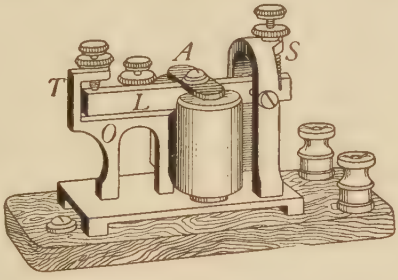


FIG. 238.—A simple telegraph sounder. (*From Tower, Smith, Turton, and Cope's Physics.*)

the key, and the bell in series as shown in Fig. 237. Discover how the bell operates. Of what use is the electromagnet? Is soft iron used? Why?

2. Examine the details in the construction of a telegraph sounder, Fig. 238. Connect up two sounders, two keys, and two cells as shown in Fig. 252. Use the gas pipes for grounding purposes. Of what use is the electromagnet? Is soft iron used? Why? What is the purpose of the key? When is the circuit closed? Open? In which case is the iron core a magnet?

3. Examine a toy motor. Locate the various electromagnets. Those which are fixed and do not move are called the *field magnets*. Those that rotate between the poles of the motor are called the *armature magnets*. In Fig. 239 is shown a simple two pole armature. It is made of soft iron wound with wire. The ends of the wire are fastened to a split ring called the *commutator*. The commutator and the armature are fastened to a common shaft or axle upon which they rotate. Two brushes resting on the commutator lead the current into the wire coils of the armature.

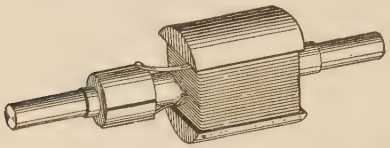


FIG. 239.—A two pole armature and its commutator. (*From Tower, Smith, Turton and Cope's Physics.*)

Connect the cells in series with the toy motor and key. The arrangement is the same as that when the electric bell is used; but in place of the bell use the toy motor. Close the circuit. Make a study of the motor while it operates. Hold the compass at various places about the field magnets and discover which is N-pole and which S-pole.

Does the motor change electric energy into mechanical energy? Are electric motors used to do work? Give instances.

4. Make a written report telling how to make a simple electromagnet. Describe how it is used in the electric bell and telegraph. Give the uses of electric bells and telegraph instruments and tell how such instruments or machines aid in the work of the world.

Describe the electric motor as a machine for putting electric energy to work in the performance of labor. Give instances.

Which is the more convenient, a steam engine or an electric motor? Give instances.

THE DYNAMO (DEMONSTRATION BY INSTRUCTOR)

Object.—To make a study of the construction of a simple dynamo and to observe it in action.

APPARATUS.—Hand power dynamo and miniature lamps of a voltage suitable to the dynamo or a toy motor. Sensitive galvanometer. Horseshoe magnet.

MATERIALS.—Several yards of insulated copper wire #18, or smaller.

PROCEDURE AND OBSERVATIONS.—1. Set the galvanometer on the table and by means of a cell show how the instrument records the presence of a current. No details of construction are necessary.

2. Select a piece of wire about 10 ft. long and attach its ends to the binding posts of the galvanometer.

3. Pass a single strand of the wire quickly between the poles of the horseshoe magnet and have the pupils observe the effects in the recording device on the face of the galvanometer.

4. Make a loop and pass it over the pole of the horseshoe.

5. Repeat with 2 turns in the loop; then 3; then 4; and so on, until the movement in the galvanometer is considerable.

6. Bring out the fact that *a current is recorded only while the coil is in motion in a magnetic field;* only while work is being done is a current being generated.

7. Repeat the experiment with coils having a number of turns in the wire.

8. Wind several turns about the armature of the horseshoe magnet. As the armature is put in place and removed note the effects recorded by the galvanometer.

9. Rotate the armature in one or more complete turns just above the poles of the magnet and observe the effect. The arrangement is a crude device for generating electric currents and is a simple form of *dynamo* in which coils of wire are made to cut magnetic lines of force.

10. Exhibit the armature of a dynamo of the two or three pole type. Call attention to the commutator and its relation to the brushes that conduct away the current.

11. After demonstrating the parts of the dynamo put it together; connect it with a galvanometer. Turn the armature a trifle, and observe the effect recorded by the galvanometer.

12. Replace the galvanometer with miniature lamps or a toy motor, and generate sufficient current to operate the lamps or motor.

13. Develop the energy transformations that have taken place—mechanical energy to electrical energy; the electrical energy to heat and light in the lamps; or back again into mechanical energy in the case of the toy motor.

14. At the conclusion of the demonstration, pupils should be able to give a brief summary of what has been done from the standpoint of causes and effects.

(*a*) A loop of wire cutting magnetic lines of force has a current of electricity flowing in it.

(*b*) The greater the number of turns the stronger the current flowing in the loop.

(*c*) A dynamo is an instrument that rotates a loop of wire very rapidly in a magnetic field for the purpose of generating electric currents.

(*d*) The faster the loop is moved or rotated the more effective is the current.

(*e*) Show the forms of energy; their transformation.

(*f*) A dynamo uses mechanical energy for making electrical energy.

(*g*) An electric motor uses electrical energy for making mechanical energy.

TELEPHONES

Object.—To make a study of the receiver and transmitter of a telephone, their relation to each other, and to the work that is performed.

Apparatus.—Two telephone receivers. A carbon microphone. A carbon transmitter. Two cells. Compass.

Materials.—Several feet of copper wire.

Procedure and Observations.—1. Remove the cap from the end of the receiver and allow the enclosed mechanism to slip out into your hand. Remove the disc from the end and observe very fine coils of wire. Do nothing to damage any part of the mechanism when making an observation study of its parts.

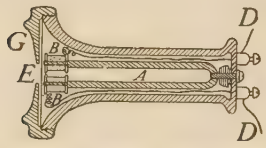


Fig. 240.—A telephone receiver. This receiver has a permanent horseshoe magnet with a coil about each pole. (*From Tower, Smith, Turton, and Cope's Physics.*)

Are the wire coils attached to a permanent magnet? Prove your answer with the compass. Is the disc made of iron or of other metal? How do you know? Do the ends of the magnet stick through the wire coils? Lay the disc on the poles of the magnet and see if there is a strong attraction for the disc.

Put the receiver together. Touch the ends of the wires to the terminals of a cell. Is there a "clicking" noise produced by the receiver (1) when the wires are touched to the terminals of a cell, and (2) when they are taken off? The clicking noise is caused by the violent vibrations set up in the disc by the heavy currents of electricity that pass through the wires in the coil.

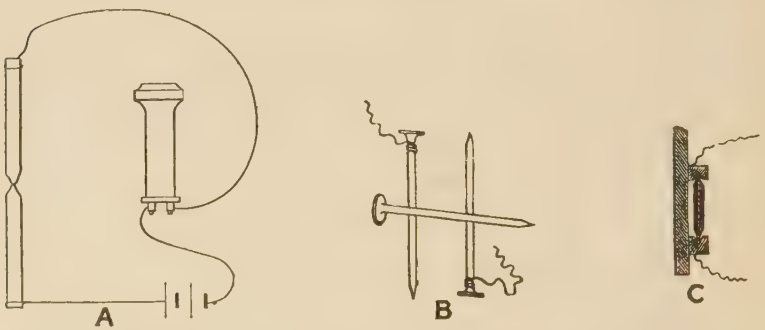


Fig. 241.—Different forms of microphones. *A*, Two carbon rods connected in a series circuit with a battery and a receiver. *B*, Three nails used in place of carbon rods. *C*, Three pieces of carbon mounted on a board.

2. By means of wires connect two receivers that are in different rooms. If the connections are well made conversations may be exchanged—one person talking into his receiver while the other listens at his. If a carbon microphone is not at hand, two pieces of carbon with wire tightly twisted about their ends may be used and connected with a battery

and a telephone receiver as shown in Fig. 241 (*a*). In place of carbon rods, nails may be used, or a carbon microphone may be constructed as indicated in the illustration.

When properly adjusted, microphones are particularly sensitive. Place a microphone on a table top with a battery and run wires into an adjoining room to a telephone receiver. Place a watch or a clock on the table by the microphone and observe whether the ticking of the watch can be heard in the receiver. All connection must be well made, and the parts of the microphone, while loosely established, must be in contact with each other.

The microphone regulates the flow of the electric currents. When the parts are put under pressure, considerable amounts of current are allowed to pass. Under light pressure small currents are allowed to pass. The heavy currents followed by the small currents cause the disc in the receiver to vibrate accordingly and to give off sound waves to the ear.

4. A transmitter on a telephone is essentially a carbon microphone very nicely constructed. Have your instructor take apart a telephone transmitter and show the arrangement of the carbon elements.

5. In place of a microphone in (4) use a telephone transmitter and carry on conversations. In which case is speech transmitted the best—with (1) two receivers, (2) a receiver and a microphone, or (3) a receiver and a telephone transmitter?

6. Report briefly on the uses of telephones and tell how they aid in the performance of the work of the world.

Work and Energy.—Energy has been defined as the capacity to do work; and work, as the overcoming of resistance. Simple machines, such as the lever or the pulley, were invented in order that man might be better able to overcome resistance whenever it was too great to be mastered by the strength of his body. A woman sweeping a floor uses a form of lever with a brush upon the end of it. Sweeping is an exhausting labor and uses up a great deal of energy. And it is quite probable that many hundreds of women have often wished for some mechanically operated machine that would do the work with less expenditure of the energies of their bodies. Many kinds of sweeping and cleaning machines were invented, but they never came into general use for the reason that their operation required greater expenditures of energy than did the old-fashioned broom.

When electricity came into general use, a vacuum sweeper operated by electric energy was invented. It was soon found that this machine was a great labor-saving device—it did not

require so much of the body's store of energy. The pressure of the hand against the broom handle was no longer needed, for electric pressure drove the new machine. In the performance of work, it is always a question of applying pressure to opposing forces. In order to row a boat, the pressure on the handle of the oar must be sufficient to produce motion. Otherwise no work will be done.

From the earliest times man made use of pressures arising from winds and running water. To apply these forces it was necessary to construct sails, windmills, and water wheels in order to convert the pressure from such sources into useful work.

Putting Steam to Work.—For centuries men saw that power could be obtained from heat, because when things were heated they expanded and produced a great deal of pressure. Also, it was known early in history that it was dangerous to heat water in closed vessels, for the confined steam created such internal pressures as to become explosive. Two thousand years ago Hero of Alexandria created a form of steam engine that still bears his name. Although a toy, Hero's engine held up to the mind of man the possibility of using heat as a source of energy. However, eighteen centuries had actually to pass by before any one succeeded in putting the impulsive force of steam to work.

In the middle of the seventeenth century several writers took up the subject of using steam pressure as a source of power. Several attempts were made, with little or no success. At the beginning of the eighteenth century the need of a steam engine became more and more urgent. Especially was this true in England, where great quantities of water had to be pumped from the mines while the miners were at work. In many places valuable mines had to be abandoned when the top layers of ore were exhausted.

To Newcomen belongs much merit, for he designed, constructed, and put into actual operation a steam engine of sufficient power successfully to operate the heavy pumps of the mines. Newcomen's engine was known as an atmospheric engine, for the reason that the pressure of the atmosphere drove the piston through a cylinder in which a vacuum had been made by condensing steam. The details of construction and the

means of operation are all clearly shown in Fig. 242. The top of the cylinder was open to the air. When the operator, *j*, turned the throttle, *n*, steam entered at the bottom and forced the piston upward and allowed the pump rod, *m*, to descend into the mine. When the piston had reached the top of the cylinder, the steam was turned off, and a small amount of cold water from a tank, *g*, entered the bottom of the cylinder and condensed the steam, producing a vacuum. The atmospheric pressure again

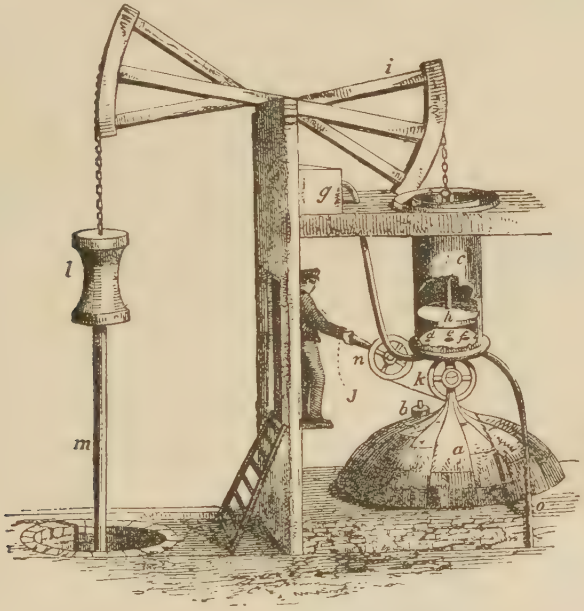


FIG. 242.

forced the piston downward through the cylinder. The action of the steam engine depended entirely upon the movements of the operator, who was required to time his motions with those of the engine. Newcomen's engines continued in use for over a half century, and at the time they were considered as perfected in every detail.

James Watt Improves the Steam Engine.—In 1757 the University of Glasgow advertised for an expert instrument-maker. James Watt was finally chosen to fill the position and in a short time won for himself a high reputation as a dexterous

handicraftsman and a clever investigator of scientific problems. During the winter of 1763, a working model of one of Newcomen's atmospheric engines was sent to Watt for repairs. In taking it apart and putting it together again, Watt saw the possibility of making improvements that would make a more efficient engine. After several years of almost continuous study, Watt brought forth a steam engine which was vastly superior to that of Newcomen and which in principle was no different from the one in use today, Fig. 243.

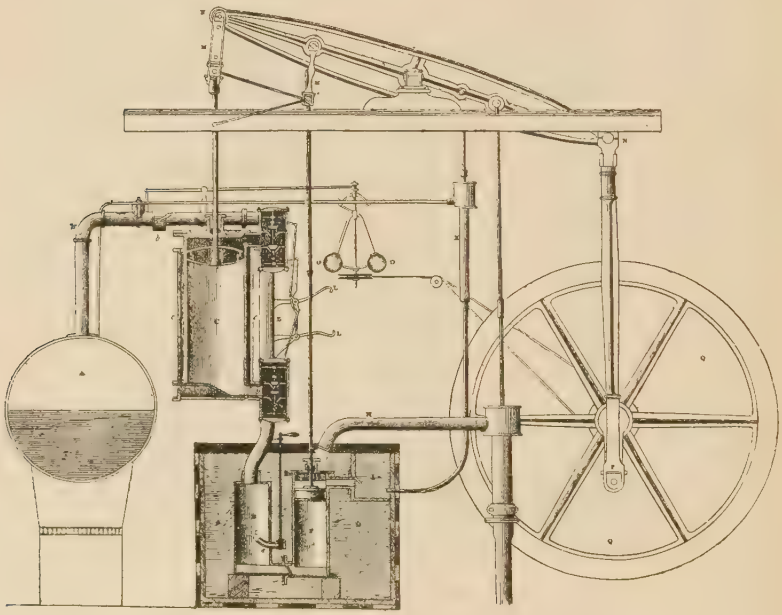


FIG. 243.—Watt's double acting steam engine.

While Newcomen's atmospheric engine was adaptable only to the operation of pumps, Watt's engine could be used for the operation of all kinds of machinery. Its piston was nicely fitted in a cylinder on the side of which was a slide valve arrangement that admitted the steam, first at one end of the cylinder and then at the other. As a result the piston head forced a piston rod forth and back and gave motion to a crank shaft on which was mounted a heavy fly wheel. During each revolution of the heavy fly wheel, it received two impulsive

forces from the steam pressure which was applied alternately from the two ends of the cylinder. The heavy fly wheel was the secret of the engine's success, for it imparted a steady and an

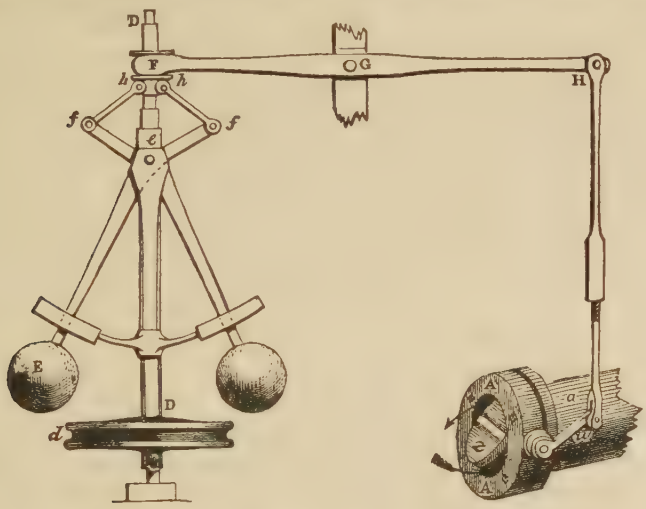


FIG. 244.—The governor and the throttle valve.

even motion to the piston and to the machinery which the engine operated. Furthermore, Watt contrived a governing device which regulated the flow of steam according to the working needs of the engine, Fig. 244. For example, when the load was light, there was a tendency for the engine to speed up, which was prevented by the governing device shutting off a proper portion of the supply of steam. When the load became great, there was a tendency for the engine to slow down, which was likewise remedied by the governing device which permitted greater quantities of steam to operate on the piston head.

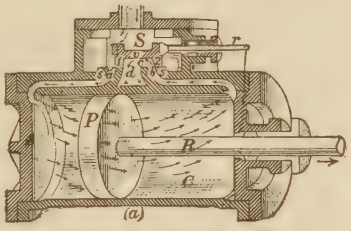


FIG. 245.—Cross section view of cylinder and steam chest of a steam engine. *s*, Slide valve in steam chest; *P*, piston in cylinder; *d*, exhaust. (*From Tower, Smith, Turton, and Cope's Physics.*)

The century following Watt's improvement of the steam engine witnessed greater changes in the material conditions

of life than had the twenty preceding centuries. There arose in this short time a new civilization which was so different from any which had previously existed in the history of the world that man has hardly yet grasped the full importance of the change. For one hundred and fifty years the steam engine held forth as the power giant of the earth. Heat energy derived from burning coal furnished such a steady and a constant flow of steam that the steam engine displaced other forms of power. Great manufacturing towns sprang up within easy reach of coal and iron. But this much is only half the tale, for man soon learned how to turn the power of steam against the other

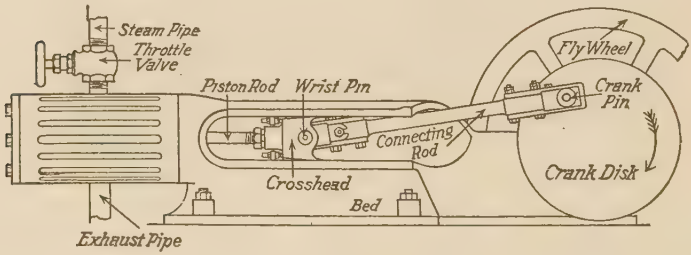


FIG. 246.—External view of a steam engine. (*From Tower, Smith, Turton, and Cope's Physics.*)

forces in nature which had heretofore challenged the strength of his puny muscles. In short he learned to use his brains in directing heat and steam to the performance of the many labors.

The Gas Engine.—In order to operate a steam engine it is necessary to have a fire box under a boiler for the purpose of changing water to steam. In this arrangement much space is taken up and a large quantity of heat is lost. During the process of combustion in the firebox, a great quantity of heat must be allowed to escape with the gases that pass off through the smoke stack. The boiler radiates a great deal of heat into the surrounding space. In the engine a large portion of heat passes off with exhausted steam that is released from the engine with every stroke. Hence to operate the average steam engine it is actually necessary to burn 100 pounds of coal to accomplish what could be done without losses with 18 pounds

of coal. Many skilled men have given the problem their time and study with the hope that some improvement might be made that would make the firebox, boiler, and steam engine a more economical device for transforming heat energy to mechanical energy. While some improvements have been made, the general average for all engines is still low.

Very early the idea existed that if all combustion processes could be carried on within the engine itself, a saving in fuel would result. The gas engine is planned on this principle. Combustible gases mixed with air are led into the cylinder chamber above the head of the piston. When the mixture is ignited, combustion process takes place at once with the formation of large quantities of new gases and the liberation of much heat. These new gases, being unable to escape at the moment of their formation, create a very great pressure within the cylinder. The presence of the heat tends to expand the gases and to increase the pressure already present. The total pressure works on the inner walls of the cylinder and the piston head. Hence the piston head is forced to move in such a way as to give the newly formed gases greater space, and thus the working parts of the gas engine are set into motion.

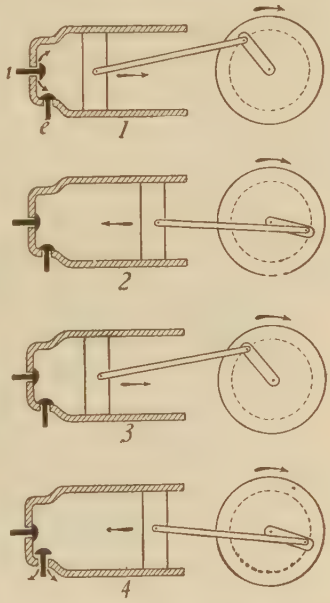


FIG. 247.—The four cycle strokes of a gas engine. (1) Intake stroke, (2) compression stroke, (3) power stroke, (4) exhaust stroke. (*From Tower, Smith, Turton, and Cope's Physics.*)

However, this is only one step in the operation of a gas engine. If the engine is to go on operating, the old and burned gases must be constantly replaced with new mixtures of combustible gases and air in order to give a constant supply of power. This is all made possible by a simple arrangement of valves that are so operated and controlled as to allow the burned

(dead) gases to escape (exhaust) and fuel gases to enter at just the right moment. In order, then, that a gas engine may continue in operation, four steps or processes must be provided for, Fig. 247.

1. An intaking of a fuel gas and air (*oxygen*). *Intake stroke.*

2. A compression of the fuel gases in order to get the greatest effect when they are exploded. *Compression stroke.*

3. An ignition or firing of the gases in order that an explosion (combustion) of fuels may occur. *Power stroke.*

4. An exhausting (sweeping out) of burned and exploded fuels. *Exhaust stroke.*

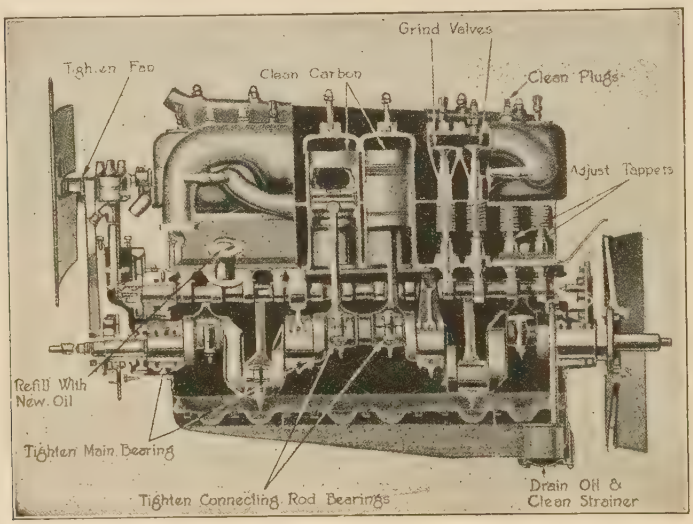


FIG. 248.—The mechanism of a modern automobile gas engine. (*From Tower Smith, Turton, and Cope's Physics.*)

In order to bring about the four processes the piston has to make four strokes—two up and two down. During these four strokes the crank shaft and fly wheel make two complete revolutions. But during the two revolutions only one of the strokes is a *power stroke.* The other three strokes are engaged in bringing new gases, preparing them for explosion, and throwing out old gases. These three strokes are called the *idle strokes* for the reason that no power is contributed by them to the performance of the engine. Indeed these three

strokes take up power during their movement through the cylinder. This power is obtained from the *spin* (inertia of a moving body, Chapter XIX) or the momentum of the rapidly rotating flywheel, which is thus seen to play an important part in the operation of the engine. Gas engines that operate in the manner described are spoken of as *four-cycle* gas engines.

The Uses of the Gas Engine.—From the standpoint of the source of energy and construction a gas engine is essentially no different from a steam engine. In each case heat energy is converted into mechanical energy. In each there is a cylinder containing a piston head that operates a piston rod attached to a crank shaft and a flywheel. Both are operated by hot compressed gases which seek to escape by driving a piston through a cylinder. The essential difference is that in the gas engine the processes of combustion all take place in the cylinder.

This one difference has brought the gas engine into extensive use, for there is no necessity of a cumbersome firebox and boiler and the presence of large amounts of solid fuels. Hence the gas engine has attracted attention from the first by reason of its extreme lightness in proportion to the power that it is able to develop. In one design—the Gnome—used in airplanes, a 100 horse-power engine weighs only 220 pounds or 2.2 pounds for each horse-power developed.

Today the gas engine operates machines of every kind. It is as useful in the country as in the town. It is as adaptable to domestic uses as it is to those of the factory. As a means of locomotion, it is used to drive railway coaches, boats, automobiles, motor trucks, and airplanes. On the farm the gas engine has solved acute labor problems and has increased the food production. In the motor car and airplane it has become the only source of power. Since it came into use in the latter part of the 19th century, the adoption of the gas engine into the affairs of life marks off the beginning of the 20th century more effectively than any other agent resulting from the hand of man. The increase in material progress, the ease of social intercourse and communication of the population, the growth of trade, the great quantity of food and clothing, and the changes in our manners and customs and laws are all,

in a great measure, due to the adaptability of the gas engine to the performance of work.

Magnets and the Compass.—In many places on the earth's surface is found a form of iron ore which has the power of attracting bits of iron. In ancient times this ore was found in Magnesia in Asia Minor. Writers of those times tell about a shepherd, Magnes, who discovered particles of this marvelous ore clinging to his iron staff. Pieces of the ore found their way to the ports of the Mediterranean where they aroused a good deal of interest, and greatly excited those who were inclined to be superstitious. Such pieces of ore, that exhibited attractive properties toward fine particles of iron, were called *magnets*. This name is said to have been derived from the name of Magnes, the shepherd, who was the first to observe the action of magnetic iron ore.

Later it was discovered that whenever magnets were suspended in a horizontal position they always pointed in a north and south direction. This observation led to the invention of the compass and eventually to the dipping needle. These instruments came into immediate use on board vessels, and by their aid mariners were able to venture out of sight of the mainlands and to go in quest of more distant countries. This was the first real use to be made of the force of magnetism. The invention of the compass and dipping needle was followed by a period of scientific investigation and exploration never before known.

Facts Pertaining to Magnets.—A magnet may be defined as anything which will attract small particles of iron. There are two classes of magnets included in this definition—natural magnets and artificial magnets. A natural magnet or loadstone is a variety of iron ore which retains its magnetism after it is taken from the ground. An artificial magnet is a bar of iron or steel which at first had none of the properties of a magnet, but to which the magnetic property has been given by artificial means. In 1600 Gilbert found that artificial magnets could be made by stroking a bar of soft iron or steel with a piece of loadstone. He also found that a certain difference exists between the bar of soft iron and the bar of steel. A bar of soft iron remains a magnet and possesses all the properties of a magnet only so long as it is

near or touching a magnetic substance. But, when removed from the presence of the magnetic body, a soft iron bar loses more or less completely all traces of the properties of a magnet. A bar of steel retains its magnetism permanently, and is, therefore, said to be more *retentive* than soft iron.

If a magnet be dipped into a mass of iron filings, the filings will be seen to be attracted to the loadstone or bar magnet. Furthermore it will be observed that the greatest number of filings are concentrated at or near the ends of the magnet. If the magnet be placed under a sheet of paper, and iron filings be sifted on the sheet of paper, it will be found that the iron filings have arranged themselves into a series of lines. The lines are not in any way confused but run in a general way from one end of the magnet around to the other. These two tests show that some sort of force is acting in the region about a magnet. This region about the magnet through which the lines of force are coursing is called the *magnetic field* of the magnet. Such a magnetic field is represented by lines drawn from one end of the magnet to the other, Fig. 249.

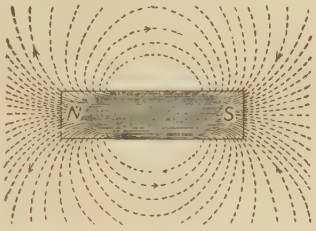


FIG. 249.—Diagram of the field of a bar magnet. (*From Tower, Smith, Turton, and Cope's Physics.*)

If a magnet is suspended by a thread or supported on a pivot so as to turn freely in a horizontal direction, it will be found to take a direction which is almost north and south. It is found, furthermore, that one particular end always points to the north while the opposite end always points to the south. If the magnet is displaced from this north and south direction, it will, after a few vibrations, settle back into its former position, the same end pointing north, and the other end again pointing south. That end of the magnet which persists in pointing to the north is called the north pole of the magnet; and the end which points to the south, the south pole.

When the north pole of a magnet is brought near to the north pole of a freely suspended magnet, the two like poles are found to repel each other. In the same way if the two south poles are brought near to each other, they will be found to repel each

other. But if the north pole of one magnet be brought near to the south pole of another magnet, the two will be found to attract each other. From the above observations we are able to state a law concerning magnetic attractions and repulsions—namely, *like magnetic poles repel each other, and unlike magnetic poles attract each other.*

Oersted's Discovery.—When Volta produced his voltaic pile and later his voltaic cell (see Chapter XVI), scientific men gave their time and study to electric currents. As time passed, many experiments were performed from many points of view

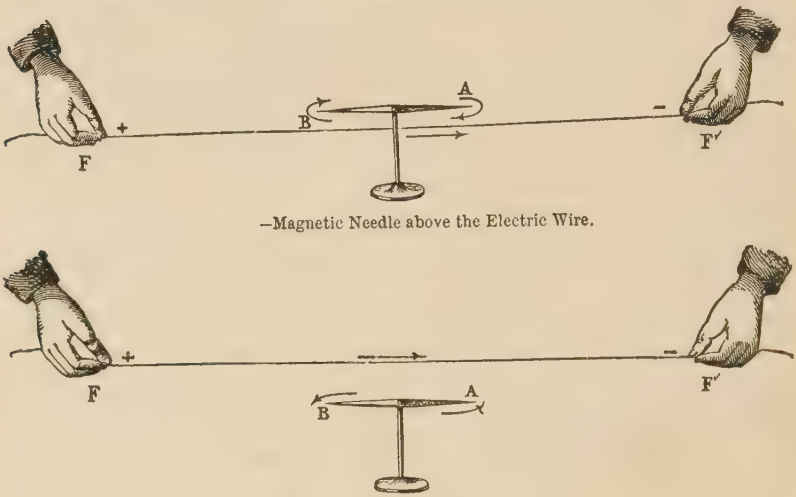


FIG. 250.—Oersted's experiment.

with the hope that some knowledge might be gained concerning this strange force. In 1819 Hans Christian Oersted was working with one of Volta's piles and accidentally observed that a nearby compass needle was greatly disturbed whenever a current was allowed to pass through the wires leading from the voltaic pile.

This discovery led Oersted to make a series of tests in which he held a wire directly over the compass needle and then directly below it, Fig. 250. In one position he found that the needle rotated toward the left, while in the other it rotated toward the right. Oersted announced his observations in a well written Latin treatise which was everywhere read with great interest

by scientific men. They saw at once the profound importance of his discovery, for it pointed out a relationship between electric currents and magnetism. In a short time men learned how to make electromagnets by passing electric currents through insulated wires wrapped about iron bars, Fig. 251. From the very beginning the electromagnet was recognized as an electric engine that was capable of setting electric energy to work.

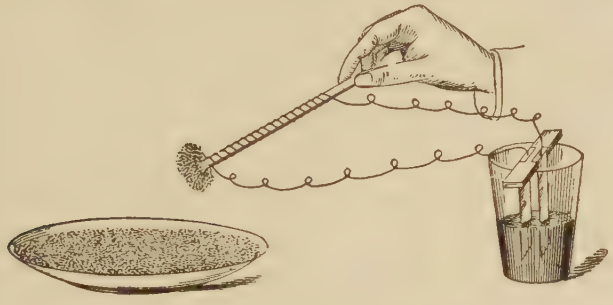


FIG. 251.—The electro-magnet.

The Electromagnet Put to Work.—Throughout the pages of history we read how the peoples of various nations and tribes tried to overcome space. The Indian made use of smoke signals as a means of quick communication. In medieval and more recent times mirrors by day and lanterns by night telegraphed messages in a more or less rapid and certain manner. The invention of the electromagnet pointed out a more dependable and far reaching method. For it was at once recognized that the electric current would operate an electromagnet at a distance as well as near at hand. But in order to accomplish this feat it would be necessary to string wires, to have a sufficiently powerful source of electric energy, and to have some sort of machine operated by electromagnets.

To us of the present day the above problem does not seem a difficult one, for indeed, any school boy might go and purchase rubber, or silk, or cotton covered wires, electromagnets, and excellently constructed batteries. Furthermore most school boys could arrange the batteries, magnets, and wire into a circuit and signal to one another through considerable distances. However true this may be today, the problem presented many

difficulties to those who first undertook its solution. At that time there were no wonderful silk-insulated copper wires on the market. There were no ready-shaped pieces of brass and iron to serve and to aid in the construction of electrical apparatus. There were no battery plates and large assortments of chemicals upon the market. The first electrical experimenters had often to make their own wire and to insulate it the best they could. The brass and iron parts had to be laboriously cut out and shaped by hand. The first batteries were made of such materials as the experimenter might find about the home or in the work shop. Under such conditions it was, indeed, exceedingly difficult to produce conditions necessary to the desired results.

No one knows who really perfected the first electric telegraph. So many men were concerned in its development that it is hardly possible to give complete credit to any one of them. In the case of the telegraph many ingenious minds contributed to its perfection. The first successful electric telegraph was developed by Wm. Cooke and Charles Wheatstone. Wheatstone was a professor at King's College, England, and Cooke was an English army doctor. In 1837 these men publicly demonstrated their system of electric telegraphing, which they installed in 1838 on a practical basis along the lines of the London and Blackwall Railway.

Five years previous to the announcement of Wheatstone and Cooke, Samuel Morse, an American artist of some repute, had been working and studying in England. Late in the year 1832 he took passage on the ship *Sully* for New York. During the month's voyage across the Atlantic the passengers of the sailing vessel became well acquainted and exchanged ideas of every sort and kind. At the time the possibility of communicating by means of electricity was the favorite topic of conversation all over Europe, and this same topic appears to have taken up a good deal of the conversation of the passengers crossing to America. Although a talented painter and sculptor, Samuel Morse was much interested in the scientific topics of the day. During the voyage he acquired considerable knowledge of the many details and problems concerned with the use of electricity

and the possibility of using it for telegraphic purposes. By the time the vessel had reached New York, Morse had already made plans and drawings of an electrical telegraphing system which he hoped to develop and bring into use. In 1835 he applied for a patent on a successfully working model. This was in the same year that Wheatstone and Cooke announced their English patent to the electric telegraph. Thus we see why England claims Wheatstone and Cooke as the inventors of the telegraph, while America proclaims Samuel Morse.

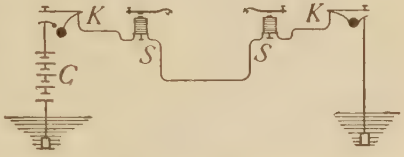


FIG. 252.—A simple telegraph circuit. (*From Tower, Smith, Turton, and Cope's Physics.*)

Of the two systems, that perfected by Samuel Morse was in many ways superior to the English system, which was large and cumbersome and not so adaptable. The Morse telegraph consists of four very simple parts: a gravity cell, *C* (Fig. 252), which generates the current of electricity; a telegraph key, *K*, or sending instrument for breaking and closing the circuit; a sounder or electromagnet, *S*, which operates the sounding lever which

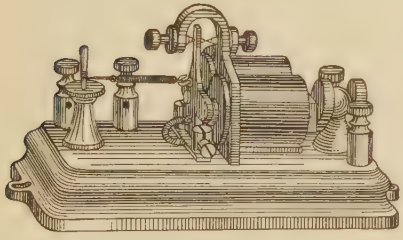


FIG. 253.—A telegraph relay. (*From Tower, Smith, Turton, and Cope's Physics.*)

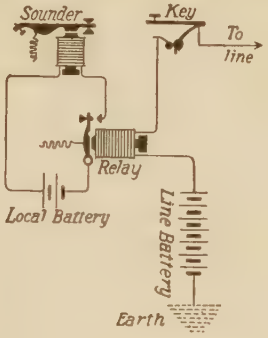


FIG. 254.—How a relay is used. (*From Tower, Smith, Turton, and Cope's Physics.*)

gives out sounds only when the current is made and broken by the key; and the wire which conducts the current from one station to another. In telegraphing long-distance, the current is not powerful enough to operate the sounding lever of the sounder. To overcome this difficulty a very sensitive relay

instrument (Fig. 253) was invented and introduced into the system so as to allow the current of a local battery to operate the sounder (as shown in Fig. 254). The feeble currents coming in on the line wire operated the lever on the relay, which made or broke the circuit passing through the sounder and local

MORSE CODE

AMERICAN		CONTINENTAL	
a · —	n — ·	a · —	m — —
b — · · ·	o — —	b — · · ·	n — ·
c — · — ·	p · — — ·	c — · — ·	o — — —
d — · ·	q — — · —	ch — — — —	p · — — ·
e ·	r · — ·	d — · ·	q — — · —
f · · — ·	s · · ·	e ·	r · — ·
g — — ·	t —	f · · — ·	s · · ·
h · · · ·	u · · —	g — — ·	t —
i · ·	v · · · —	h · · · ·	u · · —
j · — — —	w · — —	i · ·	v · · · —
k — · —	x — · · —	j · — — —	w · — —
l · — · ·	y — · — —	k — · —	x — · · —
m — —	z — — · ·	l · — · ·	y — · — —
			z — — · ·

MORSE NUMERALS

AMERICAN		CONTINENTAL	
1 · — — — —	6 — · · · ·	1 · — — — —	6 — · · · ·
2 · · — — —	7 — — · · ·	2 · · — — —	7 — — · · ·
3 · · · — —	8 — — — · ·	3 · · · — —	8 — — — · ·
4 · · · · —	9 — — — — ·	4 · · · · —	9 — — — — ·
5 · · · · ·	0 — — — — —	5 · · · · ·	0 — — — — —

MORSE PUNCTUATION, ETC.

AMERICAN	CONTINENTAL
Period · — · — · —	· · · · · ·
Comma — — · · — —	· — · — · —
Interrogation · · — — · ·	· · — — · ·
Exclamation — · — · — ·	— — · · — —
Colon — — — · · ·	— — — · · ·
Semicolon — · — · — ·	— · — · — ·
& · — · · ·	

FIG. 255.

battery. In this arrangement the sounder is operated so forcibly that an operator may be called from other duties in order to give attention to the incoming message. Furthermore Morse invented a code of dots and dashes which was again in every way more adaptable to telegraphic code systems than that put forward by the English inventors.

Morse had no financial means for demonstrating his invention in a practical way, and it seems that no one of that time could believe that the invention could be turned into a profitable investment. After several fruitless efforts Morse finally succeeded in persuading Congress to grant him $30,000 for the construction of a line between Washington and Baltimore. On May 1, 1844, telegraphic communication was established between the two cities. From time to time improvements and additions were made, until today the American telegraph systems are the most ingenious and efficient in the world.

The Telephone.—Very soon after the invention and installation of the telegraph, people in Europe and America began to look forward to the day when some one would contrive an electrical instrument by which actual conversations might be carried on. The telephone was finally invented in 1876 by the late Alexander Graham Bell, a teacher of vocal physiology in Boston University. He had spent much time and effort trying to find a way of sending several messages at once by means of a single telegraph wire. It was while at work on this problem that he discovered how to vary the strength of a current of electricity without breaking it. Finally one day he applied the results of his work to the problem of transmitting the voice. Within two months he contrived an instrument which worked so well that he exhibited it at the Centennial Exposition in Philadelphia. At this time, however, it was regarded more or less as a freak toy rather than a useful instrument.

Although people had everywhere talked much about the needs of a telephone, its growth as a practical invention was exceedingly slow. Its real usefulness, however, gradually dawned upon them, and the many conveniences derived from its uses became more and more recognized. Everywhere people found that it was an actual labor-saving device which enabled them to receive or announce news quickly. In the world of trade and exchange, it became a means whereby business could be more quickly transacted. The demands for still greater service from the telephone led to the formation of great corporations known everywhere as telephone companies, or better as "public service" companies. As these public service

corporations grew, many improvements were necessary in order to meet the growing demands of the public which they served. By scientific and patient study detail after detail was worked out until numerous improvements have been made in the first simple system established by Bell and his associates. Transcontinental telephone lines have been completed, and persons in New York are able to converse freely and easily with persons in San Francisco.

The Telephone System.—A telephone and its connections may be considered in three distinct divisions: (1) the single phone consisting of an electric bell, transmitter, and receiver (Fig. 256); (2) the wiring system that connects the subscriber with the central switch board; and (3) the central switch board.

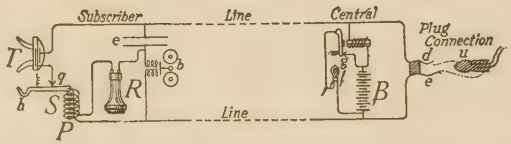


FIG. 256.—Diagram of a telephone system as used in a large exchange. (*From Tower, Smith, Turton, and Cope's Physics.*)

When one lifts the receiver from the hook, the signalling device by which the telephone is *rung* is at once cut off and a light glows above the number on the switch board at the central station. The attendant of the switch board makes the connection between the two parties that are to converse. When one is speaking into the transmitter, the sound waves of the voice strike the thin metallic plate at the end of the mouthpiece and cause it to vibrate. The vibrations of the metallic plate produce variations in the current of electricity which is flowing through the wires. When the varying currents of electricity pass through the coils of the receiver, they cause the thin metallic disc in the end of the receiver to vibrate in accordance. A varying current of electricity is one that is now weak and now strong, or of any degree of strength between weak and strong. The weak and strong currents attract or repel the disc with varying degrees of force, and thus the disc gives off to the ear an exact reproduction of the voice of the person speaking.

The Utility of Telegraph and Telephone.—No mechanical inventions of modern times have been more useful to society than the telegraph and telephone. While the telegraph preceded the telephone by about forty years, the telephone has been more useful to society in the past forty years than the telegraph. The telephone has extended its wires over millions of miles and serves millions of people. Without counting the great number of "independent" companies, the Bell company has in operation over 20,000,000 miles of wire and nearly 10,000,000 substations. It cares for nearly 30,000,000 calls daily, which is more than 100 calls per year for every man, woman, and child in the United States. This number of communications is greatly in excess of the combined total of messages cared for by the United States Post Office Department and the telegraph service.

The Western Union Telegraph Company alone has in operation nearly 240,000 miles of poles and cables that support about 1,700,000 miles of wire. This company cares for more than 75,000,000 messages yearly. These messages make possible the news of the world that is daily brought to us in the morning paper. Market transaction and Government business of every sort are promptly and quickly dispatched by means of the telegraph.

The telegraph and telephone do much more than put people into communication with one another. The fact is that these devices enable persons to communicate with each other more rapidly, more fully, and more frequently from any distance than was formerly the case. This constant interchange of ideas promotes personal welfare, community welfare, and greater national unity. In olden days messages travelled no faster than the horse or the steam engine could carry them. Now they go round the earth in a few seconds. The alphabet, the printing press, the telegraph, and the telephone are the links in the chain of human activity that bring the people into closer relationships and promote friendships and social and business interests. How life was carried on before man learned how to make electricity his bearer of messages, can hardly be understood under present conditions of living.

The Dynamo and the Electric Motor.—The whole history of human civilization may be told as a history of successful inventions. The story of how man sought to light his home with a better source of artificial light is a story that carries from the prehistoric firebrand down to the modern tungsten lamp and its relation to the flowing currents of electrical energy. In the days of Volta and Oersted all the currents of electricity were produced by means of batteries. When Oersted discovered that there were magnetic lines of force about a wire carrying a current of electricity, scientists of that day saw that flowing electricity could be used to obtain magnetic effects —electromagnets. Now scientists are in many ways like very small boys who, seeing a toy engine run forwards, take immediate steps to see if it cannot be made to run backwards. When scientific men saw that electric energy could be converted into magnetic energy, they wondered if magnetic energy could be changed back into an electric energy. The question in such a case is always—How can it be done?

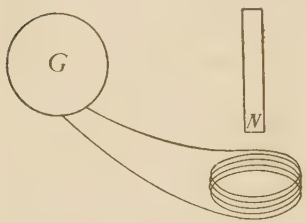


FIG. 257.—The moving magnet induces a current of electricity in the wires of the coil. (*From Tower, Smith, Turton, and Cope's Physics.*)

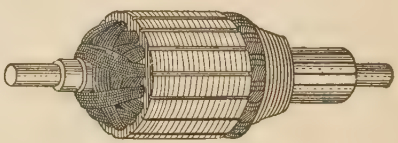


FIG. 258.—An armature and commutator mounted on a shaft. (*From Tower, Smith, Turton, and Cope's Physics.*)

In 1831 two famous scientists, Joseph Henry in America and Michael Faraday in Europe, hit upon a scheme for solving the problem. When a magnet was plunged into a coil of wire connected with a galvanometer, they discovered that a current of electricity was caused to flow through the wire, Fig. 257. This gave the world an idea, which was, of course, to invent a machine in which magnets, or electromagnets, were made to move through coils of wire; or coils of wire to move in magnetic

fields. As stated in Chapter XVI, this was accomplished by the rotating of a loop of wire in a magnetic field. (See Fig. 163.) A single loop, of course, is not used, but a great number of loops of copper wire are wound about an iron core called the armature, Fig. 258. The ends of the various loops of wire are fastened to a commutator that is fixed to the shaft that passes through the armature. When this arrangement is rotated in the magnetic field that exists between the poles of two magnets or electromagnets, an electric current flows through the wires that connect with the brushes that bear on the commutator. The arrangement of electromagnets, the armature and armature coils, the commutator, and brushes is well understood only when one has made the study relative to dynamos and motors as outlined in the demonstration at the beginning of this chapter.

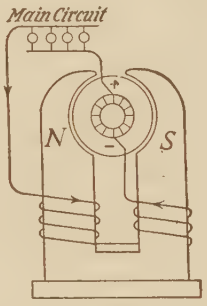


FIG. 259.—A dynamo. (*From Tower, Smith, Turton, and Cope's Physics.*)

Most of the toy forms of dynamos will serve either as a dynamo or as a motor. That is, when they are operated by an outside force—mechanical energy—an electric current will flow through the wires connecting the brushes. The strength and amount of current depends upon the size of the machine and the speed with which the armature is propelled. When a battery is connected to the brushes of the machine, the armature is made to rotate and will, of course, operate machinery. In short, a dynamo is a machine that converts mechanical energy into electrical energy, while the electrical motor does the reverse—changes electrical energy into mechanical energy.

These two machines, dynamo and motor, are of the greatest importance in our every day life. The dynamo can be operated by water wheels (Chapter XVI), wind mills, and steam engines. No matter where the coal fields or the water falls may be located, the dynamo may be set up and connected with a water turbine or steam engine. The current thus generated may be conducted to distant places, and there be made to operate the electric motor in a vacuum sweeper, a dentist's drill, the huge

presses that turn out the daily paper, or the massive machinery of large factories.

Of all the forces in nature that man has harnessed, none has lifted greater burdens from human shoulders than has the force of electricity. Throughout the United States alone there are dynamos that generate electrical energy equivalent to 20,000,000 horse-power. The electric power and light industry throughout the United States represents an investment close to $5,000,000,000 and provides employment for about one half a million people. This wonderfully organized industry serves daily over 70,000,000 people with light and power at a rate far cheaper than that in days of the candle and the horse. In order to supply this enormous amount of energy the electric light and power industries consume annually over 40,000,000 tons of coal and 12,000,000 barrels of oil. A recent survey shows that this industry alone pays out annually three and one-half billion dollars for service and property that would not exist if electric service coöperations were not in existence. To enumerate its many services and to set forth the many ways by which electricity is adapted to our everyday life would require a book of several volumes. In short, electricity is indispensable, and without its aid we should be compelled to return to the manners and customs that were existent in the early part of the 19th century.

Projects

1. To make a study of the various types of water wheels and their uses at the present time in various countries of the world.
2. To make a study of the mining and the refining operations of copper and the uses of copper in the manufacture of electrical appliances.
3. To make a study of the uses made of the telephone and telegraph wherein they aid civil authorities in maintaining order, apprehending criminals, etc.
4. To make a list of instructions as to how to use the telephone.
5. To make a survey of the community for the purpose of determining the number of public service companies that are in operation, the nature of the service rendered, and the regulations governing one of them.
6. To determine what is meant by the terms "public utilities" and "municipal ownership" and to give instances of each.
7. To find out how long-distance telephoning is accomplished.
8. To learn of the influence of the telephone on the social life of the American farmer.

9. To learn what is meant by "automatic telephone" in order to become acquainted with its principle of operation and the merits of this system of telephoning.

10. To become acquainted with the life of one or more of the following men in order to discover the conditions that led them to make important scientific discoveries and inventions.

Alessandro Volta, Hans Christian Oersted, Michael Faraday, Joseph Henry, Samuel F. B. Morse, James Watt, Robert Fulton, Eli Whitney, Elias Howe, Alexander Graham Bell, Elisha Gray, Thomas A. Edison.

Suggestion.—What educational preparation did these men have that enabled them to attack the scientific problem.

11. To demonstrate a wireless receiving set.

12. To make a study of the method used in "broadcasting" news by wireless.

13. To make a study of the construction of ocean cables and the methods used to lay them.

14. To become acquainted with the history of the development of wireless telegraphy and to give an outline report upon this topic.

15. To become acquainted with the history of the development of the airplane and with its influence upon society.

16. To give an account of the invention of gunpowder and the part it has taken in the progress of civilization.

17. To give an account of the early forms of "horseless carriage" and the conditions that finally led to the development of the automobile.

18. To compare and contrast the usefulness of the seven wonders of the ancient world with those of the modern world.

The seven wonders of the ancient world were: Pyramids of Egypt, Pharos of Alexandria, Hanging Gardens of Babylon, Temple of Diana at Ephesus, Statue of Jupiter by Phidias, Mausoleum of Artemisia, and Colossus of Rhodes.

The seven wonders of the modern world are: Wireless Telegraph and Telephone, Telephone, Airplane, Radium, Antiseptics and Antitoxins, Spectrum Analysis, and X-ray.

SECTION II

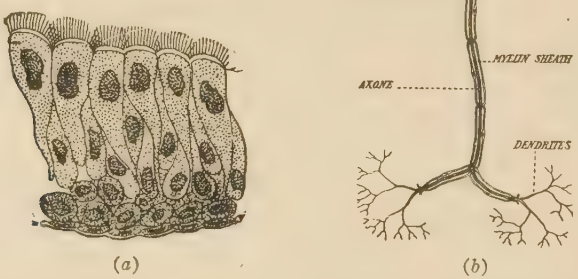
CONDITIONS OF LIFE AND GROWTH

Living and Non-living Things.—From a life full of experiences we know whether an object is, or has been, alive. Yet it is not easy to describe just what it is that convinces us regarding the presence or absence of *life*. We speak of an animal or a plant as a *living organism* and more often as an *organism*. We recognize an animal from the make-up of its several parts—muscles, brain, heart, eyes, ears, legs, etc.—which are known as organs. Yet an automobile is also made up of many closely related parts—engine, transmission, wheels, lighting device, radiators, etc.—and we never speak of an automobile as an organism. We know that the automobile is not alive, and yet just what we mean by the terms *life* and *living* no one has been able to tell.

In another way an automobile is similar to an animal organism. When fuel oils are properly vaporized and mixed with air and are conducted into the engine head and there exploded, heat energy is transformed into mechanical energy, which is capable of causing locomotion. In the body digested foods and inspired air give rise to heat energy, which also is capable of producing locomotion. In this connection we have a vital difference. As the engine continues to operate, its moving and rubbing parts wear off, with no ability on the part of the engine to replace the worn-off portions. In the healthy animal or plant body it is different. Injury to or wear of their parts is accompanied by repair and renewal. This vital difference goes far to distinguish a living object from a non-living object.

Another fundamental difference between a living and a non-living object is that a living object undergoes an orderly cycle of events—birth, youth (growth), maturity, and death—as against the more permanent or changeable conditions of existence of non-living things.

Finally, whatever life may be, we never see it in operation except in connection with a substance called *protoplasm*, which is found both in plants and animals. While it is made up of elements—carbon, hydrogen, oxygen, nitrogen, etc.—which are also found in lifeless materials, protoplasm is more highly organized than any other known substance. When we peer into a microscope and see cell-like bodies—amoeba, paramecium, vorticella—at work, we are observing bits of highly organized protoplasm performing all the functions of life. The cell forms the unit of protoplasm wherever found. In the human organism we have muscle cells, nerve cells, bone-making cells, liver cells, and many other varieties so organized as to be able to perform special kinds of work.



(*a*) (*b*)

FIG. 260.—Showing two of the many kinds of cells found in the human body, *A*, Epithelium cells that line the inner walls of the nose and protect the underlying tissues. *B*, A nerve cell that serves as a message bearer. (*From Brubaker's Text Book of Physiology.*)

It must not be thought, however, that protoplasm wherever found is like every other kind of protoplasm. A difference in the kinds of work performed by a brain cell and a muscle cell suggests differences in their organization and kind of protoplasm. Again, there are differences in the protoplasm found in plant cells and animal cells. While these differences in protoplasm are not very great, they are sufficient to produce vital variations between plants and animals and between the various kinds of plants.

In short the vital difference between living and non-living things is that living things are largely made of organized colonies of cells which consist of protoplasm. An automobile, a watch, or a telephone contains no vital substance that corresponds to the protoplasm found in plants and animals. Consequently, it is only the living, and they alone, (1) that undergo processes of growth, (2) that are capable of maintaining themselves in a state of activity, (3) that respond to the action of surrounding conditions, (4) that reproduce their kind, and (5) that in a course of time degenerate and die.

Whatever is life is dependent upon protoplasm. The existence of protoplasm is dependent upon conditions with which we are already acquainted. For we already know that in order that growth and repair may take place in plants and animals, supplies of air, water, food, heat, and light are all more or less essential. In order that we may see some of the relationships and the fine adjustments made in nature for the promotion of the processes concerned with life, the theme of this unit is concerned with plants and animals and their mode of living.

UNIT I

THE PLANT

CHAPTER XXI

CONDITIONS FOR AWAKING LIFE AND GROWTH IN SEEDS

Object.—To make a study of the undeveloped plant that lies sleeping within the seed and to establish conditions that will awaken it to active life and growth.

The Importance of Seeds.—When the last snows and frosts of winter have passed before the warming winds of returning spring, the gardener and the farmer go forth with packets and bags of seeds. Mellow beds of soil are prepared. The seeds are sown. As the days pass, some very important things are taking place—the seeds sprout, and the plants come into bloom and develop fruits and grains. The farmer and the gardener return from the harvest with many thousands of pounds of seeds in the place of the few pounds which were sown in the soil beds of the spring. The farmer and the gardener keep a portion of the seeds for their own use, and the excess portions find their way to the markets and eventually to the tables of millions of people engaged in other labors of the world.

From the beginning of time, man and animals have found their best foods in the seeds of plants. When the season was unfavorable for an abundant crop of seeds and grains, man and animal suffered from food shortages. In order to make his life more certain, man collected the seeds rich in food and planted them in places where they grew more abundantly. As the plants grew he protected them from the foraging animals and ravaging insects. In time he recognized that certain conditions were favorable to the growth of his crops, while others were unfavorable and often prevented an abundant harvest. Thus he learned to irrigate the arid lands and to drain the wet and

swampy soils. Finally he learned to select the best seeds for planting, to know the right planting season, and to improve the seed bed in which the crops were grown.

The crude implements—the wooden spade, the ox plow, the hand sickle, the cradle, and the flail—did not permit the planting and harvesting of large areas of crops. Indeed the family found it difficult to produce enough wheat, or barley, or corn to satisfy their own needs. Today it is very different. The farmer is provided with steel plows and harrows, planting machines, reapers and binders, and thrashing machines. With this equipment vast fields are plowed and made into ideal seed beds. The planting machines—seeders—plant the seeds quickly and at the proper depth. The reapers and binders harvest the fields of ripened grains in a short space of time and with little waste. Wonderful thrashing machines separate the grain from the straw and the chaff. Thus a farmer and his family are able to produce quantities of grain far in excess of their own needs.

The excess foods produced by the farmer find their way to the city and feed those who are occupied with industrial labors. When the farmer improves his farming methods and increases his harvest stores, the industrial centers become larger and more dependent upon the farmer's ability to keep the mills and the bakeries constantly supplied with grain foods. The best flour mill in Athens in the time of one of its greatest rulers, Pericles, produced only two barrels of flour in a day. One of the mills in Minneapolis produces in a single day enough flour to fill 17,000 barrels. Hence it is the great seed harvests, and they alone, that have made possible the great centers of humanity.

FOOD TESTS

Object.—To learn how to test for the presence of the various kinds of foods.

Apparatus.—Test tubes. Bunsen burner. Square of tin 2″ × 2″.

Materials.—Potato starch or other variety. White of hard boiled egg. Gelatin. Lard or Crisco. Iodine solution. Nitric acid. Ammonia water.

Procedure and Observations.—The foods—nutrients—are classified into four classes: (*a*) Carbohydrates such as starches and sugars. (*b*)

Proteins such as white of egg and lean of meat. (*c*) Fats and oils. (*d*) Mineral salts and water.

1. Place a small amount of cold water and potato starch in a test tube. Using a stirring rod work the starch and the water into a paste. Add more water and stir. Heat the contents and then allow them to cool.

Do the same for gelatin in a second tube.

Place some lard and water in a third tube.

2. Pour one or more drops of iodine solution into each of the above preparations. In which case do you observe a characteristic blue coloration? May this test be used to determine the presence of starch, gelatin, or oil? Boil some water containing a small piece of bread. Cool. Add iodine. Does the test show that bread contains starch foods, protein foods, or oil foods?

3. Place a piece (size of a bean) of raw potato (starch) in the first tube, a piece of the white of a hard boiled egg (protein) in the second tube, a lump of lard or Crisco (oil) in the third tube.

4. Add a small quantity (caution and care) of strong nitric acid to each of the above tubes. Observe any colors that develop on the surfaces of the three substances. Rinse out the acid with water, and add a little ammonia water and again look for changes in color or deeper shades of color.

The nitric acid usually produces a lemon color on the surfaces of proteins. When the acid is washed off and ammonia water is added, the lemon color develops into a deep orange color and thus proves the presence of a protein food. Apply the test to a flake of gelatin. Conclusion.

5. Prepare three pieces of paper $2'' \times 2''$. Place a small quantity of starch in the center of the first piece; gelatin on the second; a speck of lard on the third. Place the square of tin on the ring stand and heat it with a Bunsen flame. Turn out the flame. Lay the paper with the speck of lard on the surface of the warm tin and allow it to remain a minute or so. Remove the paper and hold it up to the light. Is there a translucent oil spot?

Repeat the test with the paper containing starch.

Repeat for the paper with gelatin.

Which one of the three classes of foods—starches, proteins, and fats—produces oil spots on a piece of paper?

6. Place a small quantity of starch in the center of the iron square and heat strongly until only a white residue—ashes—remains. The ash is made up of mineral salts which are noncombustible.

7. Place some dry flour in the bottom of a test tube. Holding the tube in a horizontal position heat the bottom end of the tube. Observe the escape of steam and its condensation on the cold walls of the tube.

Summarize the test for detecting the presence of starches; of proteins; of fats and oils; of mineral salts; and of water.

SEEDS AND FOODS

Object.—To apply characteristic food tests to various kinds of seeds in order to determine the presence or absence of food materials within their structures.

APPARATUS.—Test tubes. Bunsen burner. Mortar and pestle. Square tin 2″ × 2″.

MATERIALS.—Iodine solution. Nitric acid. Ammonia water. Beans. Peanuts. Wheat. Corn. Beans soaked over night.

PROCEDURE AND OBSERVATION.—1. Place one or more beans in a mortar and by means of the pestle grind them to flour. Transfer the bean flour to a test tube, add some water, boil, cool, and test with iodine. Repeat with corn and wheat. Conclusion.

2. Break open one or more soaked beans. Observe the color of the parts. Boil thoroughly with water. Pour off the hot water and add strong nitric acid to the hot portions of the beans. Observe the color. Rinse with water and add ammonia water. Observe the color. Conclusion.

3. Warm (not burn) one of the halves of a dry bean and rub it strongly on the surface of a piece of paper. Without warming repeat the tests with one of the halves taken from a peanut. Conclusion.

4. Place a half of a bean or peanut upon the iron square and heat intensely. Continue the heating until the carbon is burned away. Observe the residues. Are they white? Do seeds contain mineral salts?

5. Place halves of beans or kernels of corn in a test tube and perform the test for the presence of water.

6. Tell briefly what you did, what you observed, and what you concluded in each of the above instances.

SEED STRUCTURES AND GERMINATION

Object.—To ascertain the conditions that are necessary for awakening the undeveloped plant which the seed enfolds with food supplies.

APPARATUS.—Magnifying glass. Pie plate, or shallow planting pans which are lined with cloth (sheeting or similar material).

MATERIALS.—Lima beans soaked over night. Beans. Corn. Wheat. Two planting boxes 14″ × 12″ × 6″, one filled with loam or a fine grade of soil, the other filled with sand free from loam. Two planting boxes are sufficient for a class.

PROCEDURE AND OBSERVATION.—(*A*) Examining the seeds.

1. Examine the surfaces of dry and soaked beans. Note the scar (called the *hilum*) in the hollow on the edge of the bean.

Look for a small hole, the *micropyle* (which means small gate), near one end of the hilum (Fig. 261).

Remove the seed coat, the *testa*, from the soaked bean. Examine the seed coat thus removed and compare it with the seed coat on the dry bean. Of what use is the seed coat to the seed?

2. Separate the two parts, *cotyledons*, of the bean and discover the tiny undeveloped plant that is hidden between them (Fig. 261).

3. Study the baby plant with a magnifying glass. Do you observe two tiny folded leaves, *plumule*, and a rod-like part, the *hypocotyl?* Does the free end of the hypocotyl lie near to the little opening, the hilum, in the seed coat? (Find your answer by examining a soaked bean which has not had its seed coat, testa, removed.)

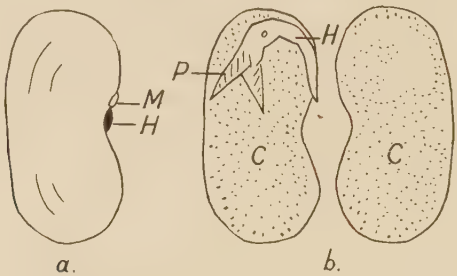


FIG 261.—*a*, A bean seed showing the hilum *H*, and the micropyle *M*. *b*, The embryo of a bean seed is composed of two cotyledons, *C*; the plumule, *P*; and the hypocotyl, *H*.

4. Carefully remove the undeveloped plant, and by means of the magnifying glass locate two scars, one on each side, which were made when the little plant was broken away from the two cotyledons. Can you see any reason why the little plant should be attached to both cotyledons?

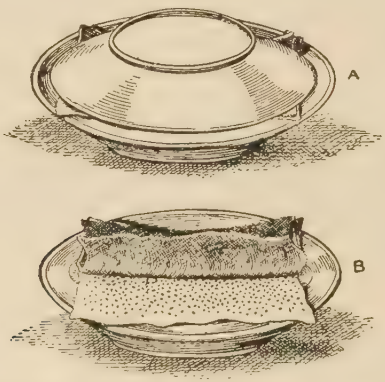


FIG. 262.—Homemade seed germinator: *A*, Closed; *B*, open. (*Farmers' Bulletin* 260.)

5. Make a drawing of the bean, the embryo, cotyledons, and baby plant. State relation and use of each part.

(*B*) Germinating the seeds. Home work.

1. Figure 262 shows the simple plate germinator and is self-explanatory. Either blotting paper or cloth may be used to receive the seed. Clean sand may be used in place of the bottom layers of cloth. Select ten seeds of each of the following: beans, corn, wheat; and any small seeds such as

flax, radishes, lettuce, etc. Place the seeds in well arranged circles or lines. The cloth should be wet, but there should not be standing pools of water above the seeds. Why?

2. Observe the seeds daily and record your observations as follows:

Seeds	Total number of seeds sprouted each day for the first ten days										Per cent sprouted
	1	2	3	4	5	6	7	8	9	10	
Beans.....											
Corn.....											
Wheat.....											

Of what value is this method of testing the germinating percentages of seeds before planting them in fields and gardens? Is this method ever used? Explain why it should be used.

How many seeds showed signs of decay and developed colonies of mold?

Beans..... Corn..... Wheat.....

What were the colors of the molds? Do molds grow from seeds or spores? Look up the answer in appropriate reference books.

3. When the seeds have germinated, sand should be sifted or sprinkled over them to a depth sufficient to cover the largest seeds, and the germinating processes should be allowed to go to completion.

4. Observe what takes place in the cotyledons of the bean. Do they come above the ground? Do they become smaller? Does the young plant obtain food from the cotyledon? Without injuring the young plant remove the cotyledons from one half of the bean plants as soon as they appear above the surface of the sand. Compare their growth and development with those retaining the cotyledons. What is the appearance and condition of the cotyledons when they finally drop from the plant?

5. Using drawings report your observations and conclusion in writing.

DEMONSTRATION BY STUDENTS

Group A; Four Students

Prepare a planting box 14″ × 12″ × 6″ deep. Fill with rich loam. Mark off four rows the long way of the box leaving a border of about 2″ around the outside. In the first row plant 4 kernels of corn 3″ deep; 4 kernels 2″ deep; and 4 kernels 1″ deep; 4 kernels on the top of the ground.

Do the same in the second row using beans; the same in the third row using 36 grains of wheat; the same in the fourth row using 36 radish or lettuce seeds. Place match stick markers where seeds are planted.

Place seeds in a warm place and exposed to the sunlight. Keep the soil damp, not wet.

Observe from day to day. Display the box every two or three days in order that fellow class members may see the results. Allow the plants to develop.

Make a final report on the proper planting depth for seeds of various sizes. Compare results with those obtained by group B.

Group B; Four Students

Same as group *A*, using sand. Compare results and conclusions with those in *A*. Which seeds send forth the stronger plants, those having large supplies of food in their cotyledons or those having little? Are soil foods essential to the sprouting seeds? Are soil foods essential to the growing plant? Does sand contain food materials? Make a full report of all observations and conclusions.

Group C; Four Students

Prepare a seed germinator similar to that shown in Fig. 262. Place the prepared germinator containing corn, wheat, beans, and lettuce seeds in a cold place or ice box. Make a report on temperature and its relation to germination.

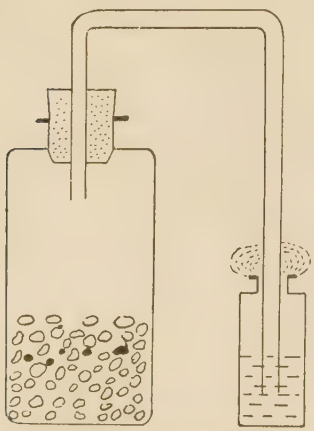


Fig. 263.—Arrangement of apparatus for collecting the carbon dioxide from germinating seeds.

Group D; Four Students

Same as group *C*, excepting that the germinator is kept full of water and in a place where all other conditions are favorable. Does the water keep the air (oxygen) away from the germinating seed? Report on conditions favorable and unfavorable to germinating seeds.

Group E; Four Students

In order to determine whether germinating seeds give off carbon dioxide, set up apparatus like that shown in Fig. 263. Place a pint of beans and some water in the larger jar and lead a delivery tube into a bottle of lime water. Pack the neck of the lime water bottle with cotton to keep the air from circulating into the space above the lime water.

Is there carbon dioxide in the expired breath of a person or animal? Is the carbon dioxide in the expired air a waste product resulting from

processes of growth and repair in our bodies? Is this the case with carbon dioxide arising from the germinating seeds? Are food materials being consumed by the germinating seed? Whence come the foods that supply the germinating processes?

Report your observations and conclusions in writing.

Seeds and Plant Life.—We who live in the temperate zones are accustomed to seeing plants in all the stages of plant activity. In the spring of the year the swelling buds of trees burst into bloom and leaf, and from every bit of earth spring tender plants of every kind. As the summer season comes to its height, plants attain their maturity and greatest degree of activity. With the passing of the summer's sun and the approach of autumn the fruits and seeds ripen and the leaves color and fade. When winter arrives the grasses and other plants are withered and browned, and the trees are bare of leaves and have none of the appearances of life and action.

Before the plants withered and browned and the trees shed their leaves, millions of seeds were dropped to earth. Throughout the winter, underneath the snow on the frozen uplands and valley lowlands, lay the baby plants enfolded in seeds of every sort. The undeveloped wheat plants, corn plants, etc., are stored away in the seeds in the protecting granaries and storerooms of the farmer. In short, during the winter season all plant life lies dormant—sleeping—awaiting the return of spring—a time favorable to the germination of seeds and the growth of plants.

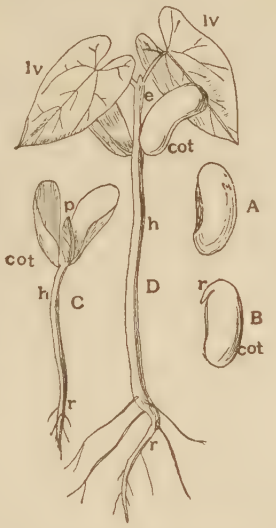


FIG. 264.—Seed and stages in germination of the white bean. *A*, Seed with hilium; *B*, seed with seed coats removed; *C*, early stages of germination; *D*, later stage; *r*, radicale; *h*, hypocotyl; *e*, epicotyl; *cot*. cotyledon; *lv*, first true leaves; *p*, plumule. (*From Harshberger's Pastoral and Agricultural Botany.*)

The Seed.—In each and every seed that is alive there is stored with the living plant a supply of the choicest kind of food. The little plant and its food supply are all snugly packed away in a protective covering or seed coat. In brief, then, the three constituents of a seed are (1) the *embryo* or young plant, (2) the

food supply either inside the embryo or in a surrounding tissue called the *endosperm*, and (3) the seed coats or protective covering called the *testa*. Although seeds vary greatly in form, the internal arrangement of the embryo and the food supply is well illustrated by a bean seed and a grain of corn.

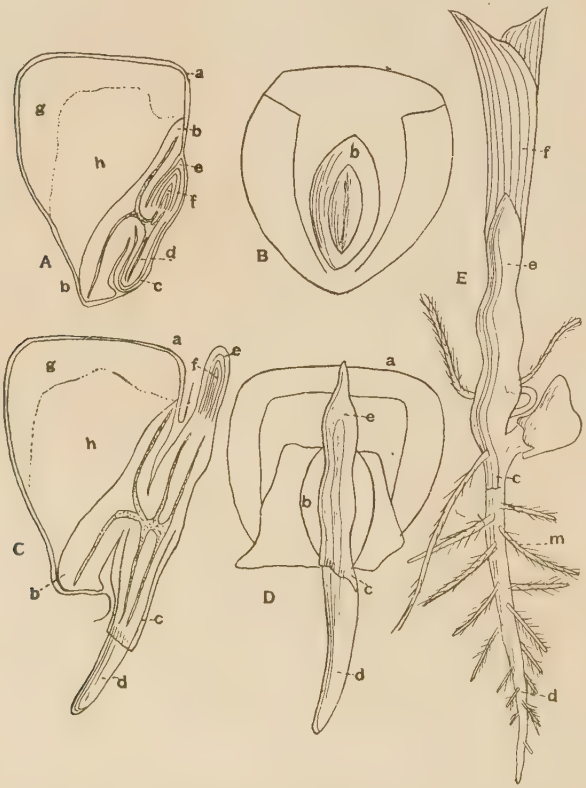


FIG. 265.—Structure and germination of Indian corn. *A*, Section of grain of corn showing position of embryo and reserve food; *B*, top or flat side of kernel; *C*, section showing early stages of germination; *D*, face view showing early stage of germination; *E*, later stage of germination when young plant has becom; independent; *A* and *b*, layers that compose the covering of the fruit; *c*, sheath; *d*, root; *e*, cotyledon; *f*, plumule; *g* and *h*, endosperm containing reserve food; *M*, secondary roots. (*From Harshberger's Pastoral and Agricultural Botany.*)

In the bean seed the seed coat contains merely the embryo, which is made up of two large cotyledons and the tiny undeveloped plant, Fig. 264. The little plant is made up of two parts—the bud called the *plumule* and a small rod-like structure called the *hypocotyl*. The two cotyledons are thick and contain a

great quantity of concentrated food for the young plant. Seeds having their food supplies stored away in the embryo in a manner similar to the bean are the pea, pumpkin, squash, flax, and many others. Plants that bear this form of seed are known as *dicotyledonous* plants.

In the grain of corn the seed coat encloses a large food supply called the *endosperm*, which has a small embryo embedded on one of its surfaces, Fig. 265. The embryo of the corn differs from the embryo of the bean in that there is only a single cotyledon which nearly encloses the plumule and the hypocotyl. During the period of germination the cotyledon absorbs the food from the endosperm. The plumule grows upward, and the hypocotyl elongates, and from its end the primary root develops. The development of the hypocotyl and the plumule is done at the expense of food materials stored away in the endosperm. Plants that bear this form of seed are known as *monocotyledonous* plants. When dicotyledonous seeds—radishes, beans, sunflowers, squash—are planted in the soil, the two cotyledons rise above the ground and become the first seed leaves of the seedling. With monocotyledonous seeds the one cotyledon remains below the ground and in constant contact with the endosperm—the food supply.

Seeds and Foods.—It has been stated already that the seeds of plants serve man and animal as their chief sources of food supply. This, of course, is due to the fact that the plant packs away in the seed the most select foods that man and animal can find. The wheat seed and similar grains are stored with starch foods. The flax seed, the cotton seed, and the peanut are full of nutritious oils. The grain of corn is stored with both oil and starch. The bean is rich in starch and protein foods. The protein foods are often called nitrogenous foods for the reason that they are the only foods that contain nitrogen in their make-up. It must not be thought that a seed contains only one kind of food, for, as a matter of fact, the food supply found in any seed may consist of all the foods—carbohydrate, proteins, oils, mineral salts, and water. For example, the edible portion of almonds is made up of proteins (21%), carbohydrates (17.3%), fats (54.9%), and the remainder, mineral salts and water (about

7%). The food values of some of the other seeds and grains are listed in the table.

FOODS OCCURRING IN SOME SEEDS, GRAINS, NUTS, AND CEREALS

Source of food	Protein, per cent	Carbohydrate, per cent	Fat, per cent	Mineral salts and water
Almonds	21.0	17.3	55.0	Remainder
Beans (dried)	22.0	60.0	18.0	
Baked beans (canned)	6.9	19.6	2.5	Remainder
Corn (green)	2.8	19.0	1.2	Remainder
Corn meal	2.5	4.5	18.5	Remainder
Flour wheat	11.4	75.1	1.0	Remainder
Oatmeal	16.1	67.5	7.2	Remainder
Peas (dried)	24.5	62.0	1.0	Remainder
Peas (green)	7.0	16.9	0.5	Remainder
Rice	8.0	79.0	0.3	Remainder
Walnuts (California)	18.4	13.0	64.4	Remainder

In thickly populated countries like China and India, where little or no animal foods may be had, the people find their chief foods in grains, seeds, and fruits.

The Germination of the Seed.—Before the vital processes concerned with growth can take place, the food supply within the seed must undergo processes of digestion and absorption in a way that is quite similar to those in our own bodies. When a piece of dry bread or cracker is taken into the mouth and chewed for a short time, it begins to taste sweet. The starch in the bread has been acted upon by the *saliva* of the mouth and changed to sugar—grape sugar. The change from starch to grape sugar is due to the presence of a *digestive ferment*—an *enzyme*—that is always present in the saliva. This enzyme brings about the first step in the digestive process of the animal.

In order to germinate the seed suitable conditions relating to moisture, oxygen, and heat (temperature) are necessary. When a live seed is brought into contact with water, it absorbs moisture ,which causes the embryo to secrete digestive ferments —enzymes. The enzymes attack the insoluble food materials that are stored in the seed and change them to soluble foods

which are taken up by the growing embryo. The swelling of the seed caused by the absorption of water and the growth of the embryo ruptures the seed coats, and the primary root makes its appearance. When the primary root is fairly well developed, the cotyledons (beans, radishes, etc.) are pushed above the ground and serve as *temporary* or *seed leaves*. Meanwhile the primary root has thrown out a complete set of secondary roots that extend in every direction in the soil bed. The little stem and bud that lie between the cotyledons develop into a thickened stem and true foliage leaves. All the while the cotyledons are growing smaller and gradually dwindling away, for the enzymes have converted the store of materials to soluble forms which the plant's circulatory system has transported to the growing parts.

During the process of germination the root system is established first in order that the plant may collect as soon as possible the soil waters which hold the mineral nutrients in solution. As soon as a few foliage leaves are formed, the young plant is capable of making its own food and living an independent life. Up to this point in its development the plant has been dependent upon the food supply stored in the seed by the parent plant. Beans, squash, acorns, chestnuts, and all large seeds produce more vigorous seedlings than small seeds, and this is probably due to the greater quantity of stored foods that occur in the larger seeds.

The Seed Bed.—Conditions favorable to germination are the first essentials when preparing the soil beds for the reception of seeds. The best conditions exist when the planting beds consist of soils that are well drained, deep, warm, and composed of black loam that contains a high percentage of well decayed organic matter and soluble nitrates. In preparing the seed bed one should not consider the seed alone, but the nature of the plant that is to develop from the seed. A grain of corn will germinate as readily in a shallow seed bed as in the same seed bed prepared more deeply. But the developing and maturing corn plants in the two instances will show considerable difference in their rate of growth. It is hardly necessary to say that the corn plant growing in the shallow bed develops more

slowly and less extensively than does the one growing and developing in the deeper soil bed Corn plants need deeper seed beds than do plants of wheat and like grains.

Wet soils lack the necessary supplies of oxygen. Germinating seeds require considerable oxygen in order to carry on the processes of assimilation of food materials that is required in the processes of growth. In wet soils the oxygen is shut out, and the carbon dioxide is retained in the water and moisture about the seeds. Under these conditions the processes of germination are soon arrested, and the young plant dies from actual suffocation.

Hard soils and clays often bake and harden under the sun's heat, especially when wetted or rained upon. The hard crusts forming above the germinating seed prevent the exit of young plants that are too weak to force their way. The seedlings of beans and peanuts are able to break through crusts of considerable thickness, but the plants arising from the small seeds are unable to do so. In such soils shallow tillage above the germinating seeds is often resorted to, and when it is carefully done accomplishes much in the way of securing a successful crop.

Large seeds that develop strong seedlings are planted at greater depths than the smaller seeds. When planting exceedingly small seeds, it is best to prepare a very fine seed bed, smooth its surface with a board or roller, trace shallow planting lines on the surface, dampen the soil with water, and then sow the fine seed in the shallow planting lines. A frame of cloth is laid over the bed to prevent it from drying out before the seeds have driven their roots into the soil, and to keep rains from washing and covering the seeds with layers of soil in which they may become lost.

Selecting and Testing Seeds.—The successful gardener or farmer gives as much attention to the character of the seeds that he plants as he does to the conditions of soil, etc. If great care is not exercised in the selection of the seed for a given crop, a great many weed seeds, the eggs of destructive insects, and the spores of destructive molds and fungi may be planted along with the seeds. Hence if a gardener or agricul-

turist gives no attention that looks toward the control of the seeds that he plants, he may be confronted with conditions that make a crop yield impossible.

In many instances farmers have planted fields to oats, barley, or potatoes, using seeds that were infected with the spores of molds and fungi that developed along with the growing plants. The fungi (smut) fed on the developing heads of grain, reduced the yield, and often consumed the entire crop. In the case

FIG. 266.—Mixture of weed seeds commonly found in low-grade alsike clover seed: (*a*), Alsike clover; (*b*), white clover; (*c*), red clover; (*d*), yellow trefoil; (*e*), Canada thistle; (*f*), dock; (*g*), sorrel; (*h*), buckhorn; (*i*), rat-tail plantain; (*k*), lamb's-quarters; (*l*), shepherd's-purse; (*m*), mayweed; (*n*), scentless camomile; (*o*) white campion; (*p*), night-flowering catchfly; (*q*), oxeye daisy; (*r*), small-fruited false flax; (*s*), cinquefoil; (*t*), two kinds of peppergrass; (*u*), catmint; (*v*), timothy; (*x*), chickweed; (*y*), Canada bluegrass; (*z*), clover dodder; (1), mouse-ear chickweed; (2), knot-grass; (3), tumbling amaranth; (4), rough amaranth; (5), healall; (6), lady's-thumb. (Enlarged.) (*Farmer's Bulletin* 382, 1909.)

of the potato the molds infected the soils about the plant and fed upon the new crop that was maturing, with the result that rots, blights, and other infections laid waste the expected crop.

In purchasing seeds upon the market we cannot expect to obtain a quality of 100%. The presence of weed seed (Fig. 266) is one of greatest evils that operates against the securing of the best crop results. The presence of weed seed among the larger seeds—corn, beans, peas, etc.—is seldom encountered. But among the smaller seeds—alfalfa, clover, blue grass, cane,

millet, oats, red top, timothy, and similar seeds—adulteration from weed seed is frequent. A simple magnifying glass quickly reveals the presence or absence of weed seeds in a sample of selected seed (Fig. 267, Fig. 268).

FIG. 267.—Alfalfa of good quality. Natural size and magnified 9 times. (*After Brown, Edgar, and Crosby, Mamie, L.: Imported Low-grade Clover and Alfalfa Seed. Bull* 111, *Part III, Bureau of Plant Industry.*)

The number of weed seeds that are sown with crop seeds is sometimes astonishing. If a sample contains as much as two-tenths of one per cent (0.2%) by weight of noxious weeds, the number of weed seeds averages nearly 1000 to the pound, or

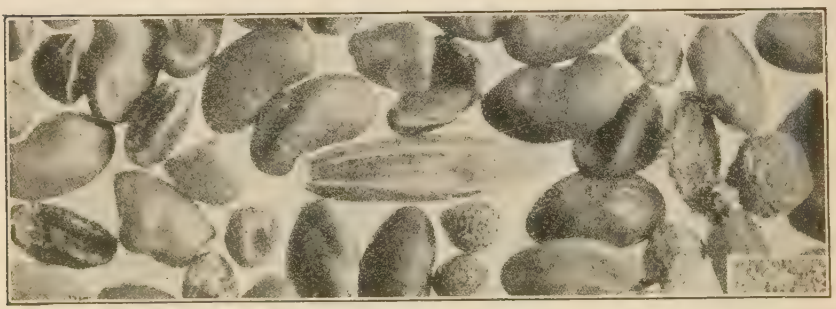


FIG. 268.—Imported alfalfa of low grade. Natural size and magnified 9 times. (*After Brown, Edgar and Crosby, Mamie L.: Imported Low-grade Clover and Alfalfa Seed. Bull* 111, *Part III, Bureau of Plant Industry,* 1907.)

60,000 weed seeds per bushel of sixty pounds. Since it costs just as much to prepare the soil for a poor quality as for a high quality of seeds, a gardener or farmer should plant only the best possible quality that the market provides.

The vitality of seeds which one proposes to plant can only be determined by an actual test of the germinating power of the seeds to be planted. In practical seed-testing a sample of 100 seeds is placed in a germinating chamber where proper conditions of germination are artificially maintained. A more simple way is to place the sample seeds between damp blotters on a dinner plate (Fig. 262) which is covered with a bowl or second plate. When cereals, clovers, vetchlings and peas are tested, *one-half of the seeds should be germinated at the end of three days;* with beans, flax, spinach, buckwheat, rye, wheat, and timothy, *one-half at the end of four days;* oats, canary grass, and corn, *one-half at the end of five days;* beets and carrots, *at the end of six days;* peas and orchard grass, *at the end of seven days.*

The importance of a high quality in agricultural seeds is being more and more recognized. The success of a nation depends wholly upon its ability to feed itself. The first source of foods is ever and only found in plant tissues. Hence the success of a nation lies in the intelligence and thrift of those who plant and till and harvest its crops. This fact has become recognized by our national and state governments. The national government has provided a Department of Agriculture, and the several states have established Agricultural Colleges and Agricultural Experiment Stations that are given over entirely to problems concerned with the study of seeds, soils, tillage, and every other phase concerned with insuring and increasing the average yield of every kind of crop. These national and state organizations are maintained out of public funds and render free service wherever such service may be beneficial to the welfare of its inhabitants.

Hence every gardener, farmer, and agriculturist should know before planting time arrives whether his selected seeds are (1) free from diseases and spores of fungi and molds, (2) free from weed seeds of every sort, and (3) free from seeds of a low degree of vitality. If he does not know how to select seeds free from these evils and possessing high quality, his state stands ready to select and to test his seeds for him and to provide information that he may wish concerning the care and tillage of the maturing crop.

The Important Cereal Crops.—Grasses are grown for their grains. Strange as it may seem to those of us who have not thought about the matter, corn and wheat and many other cereal crops all belong to the grass family. The ancient people of China, Babylonia, Egypt, and Central and North America cultivated the grasses and brought many of them to a high state of perfection. Recently a good deal of study has been given to the question of seed selection with a view of improving both the quantity and the quality of the cereal crops of every kind. Wonderful results have been obtained. Wheat that produces a greater number of grains of increased size and better quality has been brought forth. Indian corn with which the Indian of early history was acquainted has been developed and so improved that the corn harvest equals and often exceeds the total yield of other cereal crops. Improvements in the cereal

THE SIX MOST IMPORTANT CEREALS IN THE UNITED STATES

	Yield for the Year 1920, Bushels
Maize (corn)	3,232,367,000
Oats	1,524,055,000
Wheat	789,878,000
Barley	202,024,000
Rye	69,318,000
Rice	53,710,000

grains are still taking place, and as civilization advances still greater improvements are to be expected.

Monocotyledonous and Dicotyledonous Plants.—In the seventeenth century John Ray, an English botanist, was the first to distinguish two great classes of plants and to point out their several characteristics. He found that the embryos of seeds always contained, except in a limited number of instances, one or two cotyledons. In this connection he discovered that plants which developed from monocotyledonous embryos have parallel veined leaves and a plant stock that is full of pith containing bundles of fibrous masses (Fig. 269). In the case of the plants springing from dicotyledonous embryos he found them to have net-veined leaves and a woody stem covered with a characteristic bark layer (Fig. 270). He found, furthermore,

that the flower of monocotyledonous plants usually occurs in *threes* or in *sixes*, and never in *fours* and *fives* as is the case in the flowers of dicotyledonous plants. The corn, palm trees,

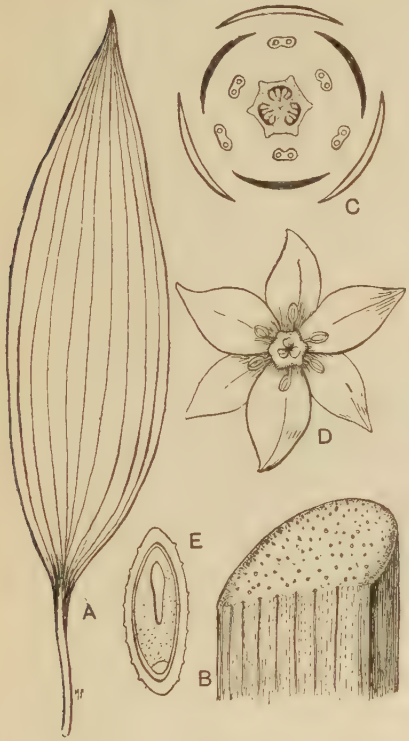


Fig. 269.

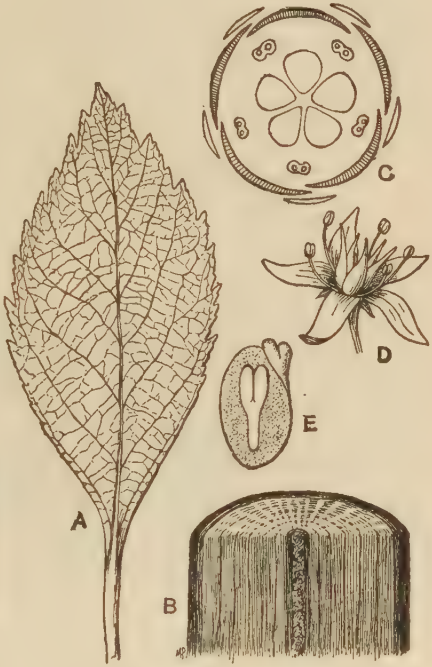


Fig. 270.

Fig. 269.—Characteristic structures of typical monocotyledonous plants. *A*, Leaf, parallel-veined; *B*, portion of stem, showing irregular distribution of vascular bundles; *C*, ground-plan of flower (the parts in 3's); *D*, top view of flower; *E*, seed, showing monocotyledonous embryo. (*From Gager's Fundamentals of Botany.*)

Fig. 270.—Characteristic structure of a typical dicotyledonous plant. *A*, Leaf, netted veined; *B*, portion of stem, showing concentric layers of wood; *C*, ground-plan of flower (the parts in 5's); *D*, perspective of flower; *E*, seed, showing dicotyledonous embryo. (*From Gager's Fundamentals of Botany.*)

and all the grasses, are examples of monocotyledonous plants; while the bean, the oak, the willow, and the clover exemplify the class of dicotyledonous plants.

Projects

1. To test the germinating power of the seeds and grains which have been selected for planting in the home garden or fields.

2. To test the germinating power of the seeds that a farmer has selected for planting purposes. Boys and girls living in cities may show their interest in the farm activities of relatives, friends, or neighbors who operate farms.

3. To learn how to test seeds in order to determine the presence of weed seeds, dirt, stones, chaff, sticks, and various other impurities.

4. To make a hot bed for the purpose of supplying the home table with early vegetables.

5. To make a hot bed for the purpose of developing the seedlings of flowering plants for the home flower garden.

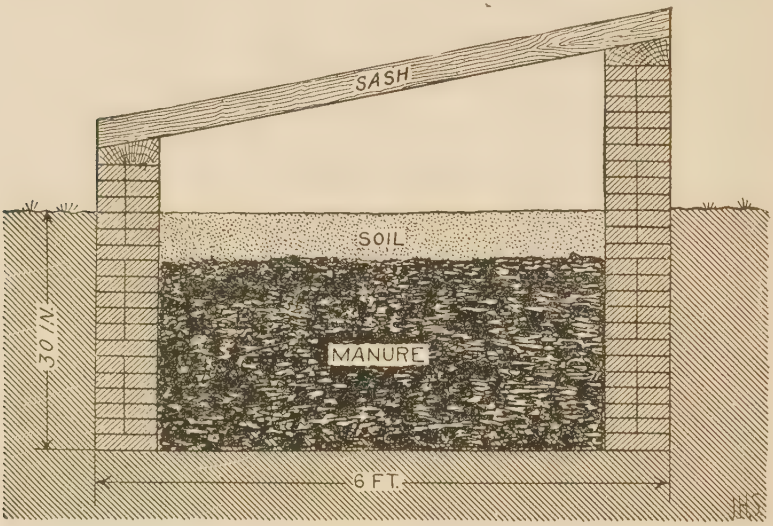


FIG. 271.—Cross-section of a permanent hotbed. The site for the pit should be on a naturally well drained land. *A* tile drain from the bottom of the pit should be provided to prevent water from accumulating in the pit and stopping the fermentation of the green manures during the period that the hotbed is in use. Hotbeds should be watered in the morning only, and then only on bright days. Excessive moisture during the night, when the hotbed is closed, provides congenial conditions for the development of mildew and destructive fungi. (*U. S. Farmer's Bulletin No.* 195.)

6. To make a hot bed for the purpose of developing seedlings of vegetable plants for the home vegetable garden.

7. To prepare a planting bed and to raise a crop of green vegetables most suitable to the home.

8. To prepare a cold frame for the purpose of keeping plants through the winter or developing seedlings for early spring transplanting.

9. To learn to identify monocotyledonous and dicotyledonous plants by their (1) leaves, (2) stems, (3) flowers, and (4) seeds. Collect, label, and display collection.

10. To learn what the national and state governments are doing in the way of developing new cereals, fruits, trees, etc.

11. To learn what the national and state governments are doing to improve cereal crops and agricultural methods.

12. To compare the total yield of cereal crops of the United States with those of Japan on the basis of (1) population, (2) acreage planted, and (3) total acreage of the nation.

13. Same as 12 with England.

14. Same as 12 with France.

15. Same as 12 with (preference).

16. To make a study of the various methods used by plants to secure the dispersal of their seeds.

Suggestion.—Collect and display seeds that exemplify the various methods.

CHAPTER XXII

CONDITIONS NECESSARY FOR THE CONTINUANCE OF LIFE AND GROWTH IN A PLANT

Object.—To observe and study green plants in order to know the conditions that enable them to manufacture foods and thus live independently.

The Independent Plant.—A short journey into the country on a summer day brings us into contact with an innumerable number of many kinds and forms of plant life. While the plants may vary as to size, form, and color, they are all in a vital way alike. They are all fixed to earth by a system of roots, all of them have stocks and stems—shortened or lengthened, and all have leaves more or less raised up into the air and sunlight. These three essentials—roots, stems and leaves—seem to be serving the plant to which they are attached in a manner that is vital to its existence.

Somehow we already know that the roots are gathering water and soluble soil materials from the ground. We also know that these soil substances gathered by the roots are sent or carried up through the stem and distributed throughout the plant. In some way we recognize that the leaf is essential to the plant and has something to do with light and air and moisture. These conditions and facts are so familiar to us that we do not attempt to grow plants in places in which the conditions are not suitable to their welfare. For example, we know that it is quite useless to attempt to raise plants in a cellar or basement which is cold and without sunlight, that plants grow better in rich loams than in hard clays and sands, and that water is a requirement.

We know, furthermore, that the plant is able to manufacture the crude materials that it gathers into wholesome fruits, nuts, grains, and many other edible substances. This much and more we have recognized from early childhood. There remain many more interesting and instructive things to know about the life and habits of plants. In order that we may be better

acquainted with the work performed by the roots and stems and leaves of plants, this chapter is given to the study of the organs and systems that are found in the plant and the manner in which they perform special kinds of work in the service of the plant.

OSMOSIS

Object.—To establish conditions whereby liquids will pass through walls composed of tissues and membranes. In short, to observe the process of osmosis at work.

APPARATUS.—Glass.

MATERIALS.—An egg. Sugar. Water.

PROCEDURE AND OBSERVATION.—1. The contents of a hen's egg are enclosed by a porous and living membrane that lines the inner walls of the shell excepting at the larger end where there is an air-chamber between the shell and the membrane. Taking great care *not to puncture the membrane*, remove from the larger end that portion of the shell which is directly over the air chamber. Place the egg in a glass and fill with water as shown in Fig. 272*A*. After a short time observe whether the membrane bulges outward as shown in Fig. 272*B*. Has water passed inward or outward through the membrane of the egg? The fluid contents of the egg are more dense than the water without the membrane. Which way do the fluids flow through the membrane, from less dense to the more dense, or in the opposite manner?

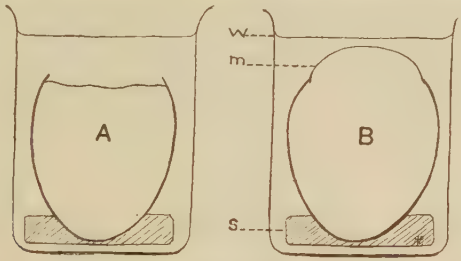


FIG. 272.—Experiment with an egg to demonstrate osmosis. *A*, At the beginning; *B*, about one hour later; *W*, water surface; *S*, support; *M*, egg-membrane. (*From Gager's Fundamentals of Botany.*)

Is there an increase of pressure on the inner walls of the membrane? Is the membrane likely to break, if the process continues?

Place the swollen egg in a strong solution of sugar and observe what takes place. Has water passed through the membrane? In what direction? The solution has a greater density than the albuminous and watery fluids within the egg. Does the water pass from the fluids within the egg to the sugar solution that is surrounding the membrane?

The *passing* or *diffusing of liquids through a membrane is osmosis*. When water passes through the membrane to the liquids within the egg,

the process is referred to as *endosmosis* (osmosis from without in). When water passed out through the membrane in order to join the denser liquid on the outside the process is called *exosmosis* (osmosis from within out). *Osmosis* may be defined as *the interchange of two fluids of different densities when separated by a porous membrane.*

Report your observations and conclusions. Use the following terms in your report: density, densities, endosmosis, exosmosis, osmosis, porous, membrane, fluids, etc.

ROOT HAIRS AND OSMOSIS

Object.—To make a study of root hairs in order to learn the nature of the service that they perform for the plant.

FIG. 273.—Showing the development of root-hairs when seeds of white mustard are germinating. (*From Gager's Fundamentals of Botany.*)

APPARATUS.—Petri dish, or a shallow dish with glass cover. Microscope. Glass slide. Cover glass.

MATERIALS.—Radish or mustard seed. Blue or dark colored blotting paper. (To save time the seeds may be germinated beforehand.)

PROCEDURE AND OBSERVATION.—1. Cut discs of blotting paper to fit the Petri dish. Place two layers on the bottom of the Petri dish. Thoroughly dampen the paper. Place a dozen or more seeds on the damp blotting paper Set the cover in place and put all in a place favorable to the germination of the seeds.

2. Observe the development of root hairs growing from the root. Observe where the root hairs are longest and most abundant.

3. Place one of the germinating seeds having root hairs on a glass slide. Place a drop of water on the root hairs. Cover the drop with a cover glass.

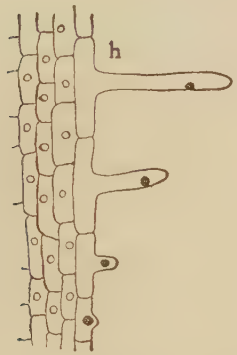


FIG. 274.

FIG. 275.

FIG. 274.—Diagram showing stages of development in root-hairs from the epidermal layer of the root. *h*, The oldest of the four root-hairs. (*From Gager's Fundamentals of Botany.*)

FIG. 275.—Root-hairs. *a*, Condition when receiving water—endosmosis *b*, Immersed in a weak salt-solution, losing water— exosmosis. *c*, same as *b*; later stage; *n*, nucleus. (*From Gager's Fundamentals of Botany.*)

Place the prepared slide on the stage of the microscope and study the appearance and structure of a root hair. Are the walls thin or thick? Is there more than one cell in a root hair? Compare with Fig. 274 and with Fig. 275.

4. Prepare a second slide using the same plant in a drop of a strong solution of salt. Observe the behavior of the root hairs toward the strong salt solution. Compare what you see with *b* and *c* in Fig. 275. Is the process of exosmosis or endosmosis taking place?

5. In order for a plant to take up water and soluble materials must the solution be weak or concentrated? Can you see any reason why a strong solution of salt poured about the roots of a plant would make it impossible for the root hairs to take water from soils in which the root system is located? Explain.

6. Report on the importance of root hairs to the plant, and tell why the walls of the root hair should be thin and the soil waters weak solutions.

ROOTS AND STEMS

Object.—To ascertain how roots and stems are able to conduct and distribute water and fluids to other parts of the plant.

Apparatus.—Microscope. Glass slide. Cover glass. Scalpel or other means of cutting very thin sections.

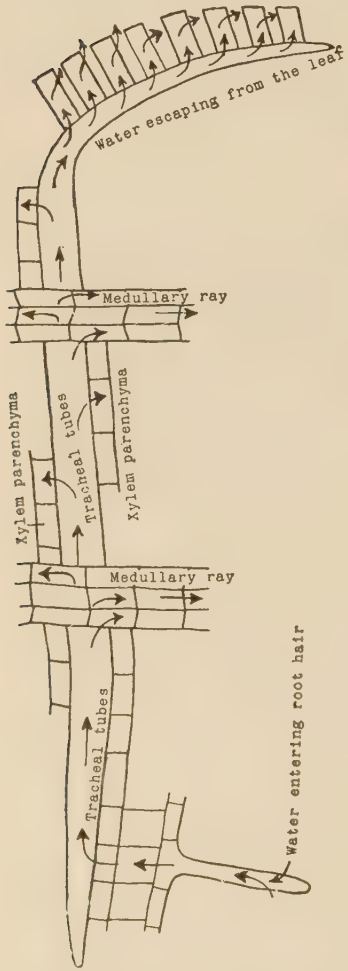


Fig. 276.—Diagram to show the path of soil water as it rises to, and escapes from, the leaves. (*From Stevens' Plant Anatomy.*)

Materials.—White parsnip or carrot. Young stem of apple or maple or other dicotyledonous stem. Stem of umbrella plant or other monocotyledonous stem. Red ink.

Procedure and Observation.—1. Cut the tip ends from sprouting parsnips or carrots and set in a dish containing red ink. Arrange some freshly cut stems of the apple or maple and of the umbrella plant with the freshly cut ends below the surface of the red ink. Cover with a bell jar and set aside for one day or longer. The stem of the umbrella plant may be used after a few hours.

2. Using a sharp scalpel shave off several cross and longitudinal sections of the stained specimens. Prepare slides of the thinnest sections. Observe them with the naked eye, the magnifying glass, and with the lower power of the microscope.

3. Locate the tube-like structures through which the ink has taken its upward course in the stem. These structures are called the *vascular bundles*. These bundles contain *tracheal tubes* and make up the *vascular* system of the root, the stem, and the leaf. The system is continuous and transports the water from cell to cell on its way from the root to the leaf. The vascular system serves the plant body in the same manner that arteries and veins serve the animal body (Fig. 276).

4. Observe the cell-like structure of the roots and stems. Observe the arrangement of cells in the various portions of the stem. Are there cells with thickened cell walls?

5. Observe the location of the vascular bundles in dicotyledonous and monocotyledonous stems. Which adds on a layer of new material each year? In which are you able to count the annular layers and thus determine the age of the plant?

6. Peel the bark layer from a dicotyledonous stem. Observe the inner layers and compare them with the outer layers. Which seem to be alive and which dead? What is the purpose of each layer?

THE LEAF

Object.—To make a study of the leaf, its important parts, and the relation of the several parts to each other and to the leaf.

APPARATUS.—Microscope. Magnifying glass. Scalpel. Glass slides. Cover glasses. Medicine dropper. One or more beakers. Bunsen burner. Porcelain evaporating dish. Needle.

MATERIALS.—Alcohol. Iodine. A potted plant. Assortment of leaves.

PROCEDURE AND OBSERVATION.—1. Sort the leaves into two groups—paralleled and netted-veined. Which were taken from monocotyledonous plants? Which from dicotyledonous (see Fig. 269 and Fig. 270)?

2. On a potted plant select a leaf having prominent veins. Hold a cork or block of wood against the under surface and cut clear through some of the veins. Does that portion of the leaf above the cut wilt? Cut across the remaining veins. How do you account for the result? Are the veins a part of the vascular system of the plant (see Fig. 276)? Does the vascular system—the veins—impart strength and serve as a support to the leaf? Summarize the uses of the vascular system as found in the leaf.

3. Roll up a sheet of paper so as to make a cylinder ½ inch in diameter. Placing a leaf of a geranium over one of the openings turn the cylinder toward the sun and look through the cylinder. Are you able to see the sun through the leaf?

Is sunlight absorbed as it passes through the leaf? What is the color of the light passing through the leaf? Has the leaf absorbed the other colors? The cells in the leaves of green plants are more or less filled with a substance called *chlorophyll* (green-leaf) which is composed of many small *chloroplasts* (green grains). It is the chlorophyll that absorbs the light.

Repeat the experiment with two leaves, three leaves, and so on until all the light is absorbed and darkness within the tube results.

(Home work.) Repeat the experiment with maple, oak, violet, plantain, rubber plant, and others. Do you find that some leaves absorb greater amounts of light than others?

4. Boil some water. *Turn out the flame.* By means of the stem (petiole) hold one or more young leaves under the surface of the hot water for a minute or so (but not long enough to brown). Transfer the leaf to an evaporating dish or wide mouth bottle containing alcohol and cover with a glass square. Set the evaporating dish on the top of the beaker con-

taining the hot water and allow it to stand until the leaf is cleared of its chlorophyll.

Using iodine, test the leaf for the presence of starch.

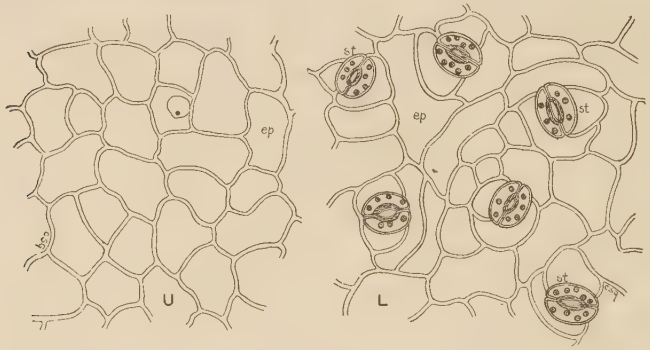


FIG. 277.—Portions of removed leaf-epidermis, *Lizard's tail*. *U*, Upper epidermis; *L*, lower epidermis; *ep*, epidermal cell; *st*, guard cells of the stomata. (*From Gager's Fundamentals of Botany.*)

5. Selecting a tender leaf and using a needle work off patches of "leaf-skin" (epidermis) from the upper and lower surfaces of a leaf. Mount on a glass slide with a drop of water and a cover glass. View the two kinds of epidermis with the low and high powers of the microscope. Compare with Fig. 277 and learn the names of the various cell-like structures. The golden granules are grains of chlorophyll that were torn from the underlying cell layers. The epidermis of the leaf contains no chlorophyll. Between each pair of kidney-like cells (guard-cells) is a tiny hole or *stoma* (Greek word meaning mouth or hole). On which surface are the stomata (plural of stoma) more numerous? What is the purpose of the stomata and guard-cells? (Consult the text of this chapter.)

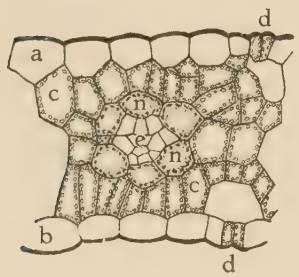


FIG. 278.—Cross-section of a portion of a leaf of Indian corn. *a*, Upper, and *b*, lower epidermis; *c*, *c*, palisade cells; *n*, border parenchyma containing starch within its chloroplasts; *e*, vascular bundle; *d*, *d*, stomata. (*From Stevens' Plant Anatomy.*)

6. Study the arrangement of the various parts of a leaf as shown in Fig. 278. Observe the position of the epidermis. Observe the position of the *chloroplasts* in the *palisade* cells and the starch in the *parenchyma* cells. Study Fig. 289 in the text.

THE LEAF AND WATER

Object.—To show that the leaves are the transpiring (water-losing) organs of plants.

Review or repeat the experiment "Plants and water vapor," Chapter IX.

THE LEAF AND LIGHT (DEMONSTRATION)

Object.—To show the relation of leaves to sunlight and the relation of sunlight to the presence of starch in the leaf.

APPARATUS.—Bunsen burner. Ring stand. Beaker. Evaporating dish. Scalpel.

MATERIALS.—A potted geranium, oxalis, or similar plant. Corks. Pins. Vaseline.

1. In order that the plant may remove the starch from the leaves place them in darkness for one or more days. Using hot water and alcohol remove the chlorophyll and test for starch.

2. Cut thin discs from the ends of the cork. Place a disc on the top surface of the leaf and one directly below. Run a pin through the two discs so as to hold them firmly against the upper and lower surfaces of the leaf. Prepare two or more leaves in this way.

3. Paint with vaseline the lower surfaces of two leaves.

4. Paint the upper surfaces of two leaves with vaseline.

5. Paint both surfaces of two or more leaves.

6. Place the plant thus prepared near a window and expose it to direct sunlight. Observe the plant daily for several days. What positions do the leaves and stems take with reference to the light that enters the window?

7. Record your conclusion concerning the reactions of leaves and stems toward sunlight.

8. Remove the corks from the leaves and observe the effects. Pick one of the leaves. Remove the chlorophyll with hot water and alcohol. Dip the entire leaf into a solution of iodine and observe the presence and absence of starch.

Is starch present in those portions exposed to the light? Is starch absent from the portions from which the light was excluded? Is light essential to the presence of starch in the leaf structures?

9. Observe the leaves painted with vaseline. Remove the vaseline from one of each of the three groups with benzine. Remove the chlorophyll with hot water and alcohol. Test for starch.

In this instance light was present, but the gases of the air (carbon dioxide) could not enter the stomata. Why are the greater number of stomata on the under side of leaves? Why are layers of hair found on the under surfaces of some leaves? Should leaves of trees be sprayed with oils and sticky substances? Explain. Is carbon dioxide essential to the making of starch? (Consult text in this chapter.)

10. Summarize the reactions of leaves toward light; the necessity of light for the presence of starch; the relation of stomata to the presence of starch; carbon dioxide and the presence of starch.

THE LEAF AND OXYGEN (DEMONSTRATION)

Object.—To show that green plants exposed to sunlight give off oxygen.

Apparatus.—Beaker. Glass funnel and test tube.

Materials.—Elodea or similar water plants.

Procedure and Observation.—Arrange apparatus, water, and plants as shown in Fig. 279. Expose to direct sunlight. Observe the escape of bubbles of gas. When sufficient has collected test for oxygen. Repeat the experiment with the plants in a darkened place. What is your conclusion concerning green plants, sunlight, and oxygen?

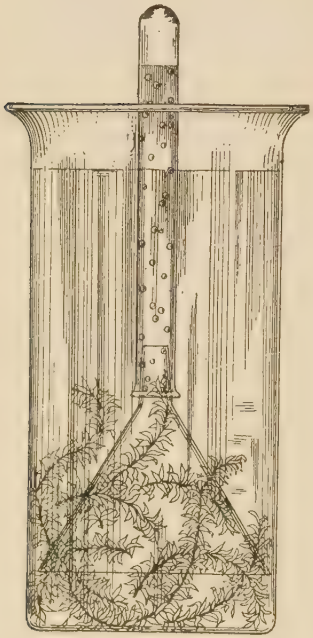


Fig. 279.—Collection of oxygen from water plants in light. (*Livingston's Palladin's Plant Physiology.*)

The Plant.—In the preceding chapter we observed the development of the plant from a germinating seed. The concern of the baby plant was to develop a root system for purposes of anchoring itself to the soil of the earth and securing supplies of soil water. While the root system was developing, a stem mounted with a bud full of undeveloped foliage leaves was pushing its way toward the surface. By the time the food supplies of the cotyledons or endosperms were exhausted, the young plant was fully equipped with root, stem, and leaves. The root was in every way suited to an existence in the earth and for the performance of special labors. The leaves were adapted to an existence in the air and for the performance of duties greatly different from those required of the root. In short it was quite clear that the leaves of the plants could not perform the work of roots, nor could the roots perform the work of the leaves. Each was especially fitted for the discharge of special labors.

Cells and Structures.—The real difference between roots and leaves is a difference in the cells that compose them. Just as a house is made up of bricks, boards, beams, etc., so is a plant composed of many different kinds of cells. The bricks and

shingles on a house serve as a protection to the boards and the beams that hold the house up and keep it together. The plant is everywhere covered (except root-hairs and parts of flowers) with a layer of epidermal cells that are tough and hard, and provide protection for the more delicate and underlying structures. Yet the cells that make up the epidermis of a plant are very far from being all alike. The epidermal cells on the root are not like those on the leaf. Even in the leaf there are different kinds of epidermal cells—the guard cells surrounding the stomata are very different from their neighboring epidermal cells. Hence when we compare the cell that is in the form of a root hair with the guard cell of the stoma, we see a great difference in form as well as a difference in the kinds of work that they perform (Fig. 278).

The water pipes and waste drains conduct water to and from the various rooms of a house. In the plant this is accomplished not by one cell but by groups of cells that form themselves into groups or tissues that make up the vascular system. The vascular system extends throughout the plant from the root hairs to the tip of the leaf on the farthest branch. The activities of the vascular system are the result of the work of a vast number of special cells that perform this one work and this work alone. In short the vascular system is composed of specialized cells for the performance of special duties (Fig. 276).

Thus every activity of every kind that takes place within a plant is the result of action within the living cell. The processes—absorption, respiration, digestion, assimilation, rejection of waste, etc.—are all carried on in special sets of cells that are most wonderfully adapted to the performance of a special kind of service.

The Plant Cell and Its Structure.—Robert Hooke, an English manufacturer of optical instruments and lenses, was the first to discover (in 1667) the plant cell. He had been examining various objects with a microscope when he observed that very thin pieces of cork appeared to be composed of a great many small compartments. He noted that the little compartments were much alike and fitted compactly like the cells in a honeycomb. From this resemblance he gave the name *cells* to the

minute structures. While the name is somewhat inappropriate for the reason that the greater number of plant cells have no resemblance to the arrangement found in a honeycomb, the name is in general use among biologists and botanists. Hooke's discovery prompted others to extend the microscopic study of plants.

In 1840 Hugo von Mohl pointed out that the slimy material within the plant cell was responsible for its life, for as soon as

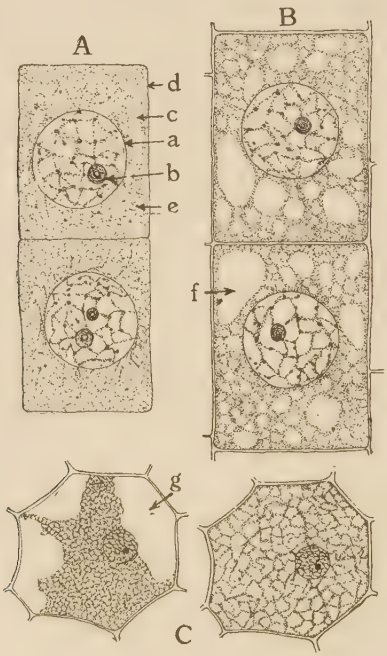


FIG. 280.—*A*, young cells from onion root tip; *d*, protoplasmic membrane; *c*, cytoplasm; *a*, nucleus; *b*, nucleolus; *e*, plastids (black dots). *B*, Older cells farther back from the root tip; *f*, vacuole, note that the cells have enlarged. *C*, Epidermal cell of Tradescantea Zebrina; in its natural condition on the right, and on the left with the protoplast drawn from the cell wall, as the result of immersing the cell in a solution the concentration of which was greater than that of the cell sap. This phenomenon is called plasmolysis. *g*. Salt solution within cell wall. (*From Stevens Plant Anatomy*,)

this substance was removed the cell no longer exhibited the characteristics of life. To this living substance the name *protoplasm* was given.

Robert Brown (1773–1858), one of the greatest of the English botanists, discovered the nucleus in cells. Hooke, Mohl, and

Brown awakened the world with their discoveries and gave rise to the cell theory, which is that plants and animals are a sum total of innumerable cells. The cells, of course, are wonderfully grouped into tissues, organs, and systems. In short, a plant cell is a living mass of protoplasm enclosed in a cell wall (Fig. 280). The cell wall (*d*) provides protection and gives shape to the delicate organism. The body of protoplasm within the cell wall is composed of *cytoplasm* (*c*), and a *nucleus* (*a*). In the cytoplasm are found the *plastids* (*e*) and the *vacuoles* (*f*). Within the nucleus are found the *nucleolus* (*b*) and other structures beyond the consideration of this course.

The Cytoplasm.—Throughout the life of the cell the cytoplasm has many things to do. Its vacuoles appear to be filled with solutions of various substances known as *cell-sap*. Many times insoluble solids, such as crystals and grains of starch, are observed in the cell-sap. When foods are to be stored away within the cell, we find them stowed away in the meshes that run through the cytoplasm. It is probably true that the cytoplasm is able to secrete digestive ferments which are capable of digesting the stored foods. The digested foods release energy and provide materials for growth and repair.

The Nucleus.—In the performance of its labors the cytoplasm is never independent of the help or presence of the nucleus, for all typical cells are provided with such a structure. If the nucleus is separated from the cytoplasm, the cell dies. Yet it is not quite correct to refer to the nucleus as the "seat of life" of the cell, for other portions of the cell are necessary to its existence and welfare. Because the nucleus enters into so many of the activities of the cell, it is regarded as the most essential part of the bit of protoplasm.

The Plastids.—Scattered throughout the cytoplasm of the cell are found minute masses of specialized protoplasm which are known as plastids. They vary in size and form and are classified according to their color: (1) white (leucoplasts), (2) green (chloroplasts), and (3) yellow, orange, or red (chromoplasts). The three classes of plastids, while performing different functions, are not greatly different from one another. The leucoplasts may become chloroplasts; and the chloroplasts, chromo-

plasts. For example, a green tomato is green because of the chloroplasts that are present in the cell structures; but as the tomato ripens, the chloroplasts become chromoplasts, which give to the ripe tomato its red color. The chromoplasts impart red, orange, and yellow colors to flowers and fruits. The chloroplasts secrete a material known as chlorophyll-green, which is used by the cells in the leaf for arresting the sun's energy, which the leaf cell uses in the manufacturing of food. These in brief are some of the few services rendered by the plastids to cells. They are essentials upon which the well-being of the cell and the welfare of the plant are dependent.

Growth and Repair in the Cell.—On account of the vital processes that are always taking place within the bodies of plants and animals, the living substance in a cell is continually undergoing destruction. The continual destruction within the cell is accompanied with continual construction—growth and repair. The parts which are being destroyed are constantly replaced with new materials. Furthermore, new protoplasm is continually being formed. All this is due to the power of protoplasm, which is able to take non-living materials and transform them into living substance—protoplasm.

Cell-division.—Since protoplasm has the power of transforming non-living substances into protoplasm and thus making itself more abundant, it might be suspected that cells had the power of producing other cells in every way like themselves. When the existing conditions are favorable, the bit of protoplasm within the cell brings about a series of deep-seated changes which finally result in the formation of two or more cells in the place of the original cell. The various stages that take place in order to bring about the existence of two cells from the original cell are best set forth in the series of diagrams shown in Fig. 281. As shown in the illustrations the nucleus divides into two parts. Each part journeys to different parts of the cell, after which the separation becomes complete. The two young cells resemble the parent cell except that they are smaller. When these become the size of the parent cell, they each in turn divide. This method of reproduction in cells is known as the *process of fission*. In this method of reproduction the new cells have all the

characteristics and tendencies of the parent cell. Hence the new cells carry on the work of the parent cell without interruption or loss of time.

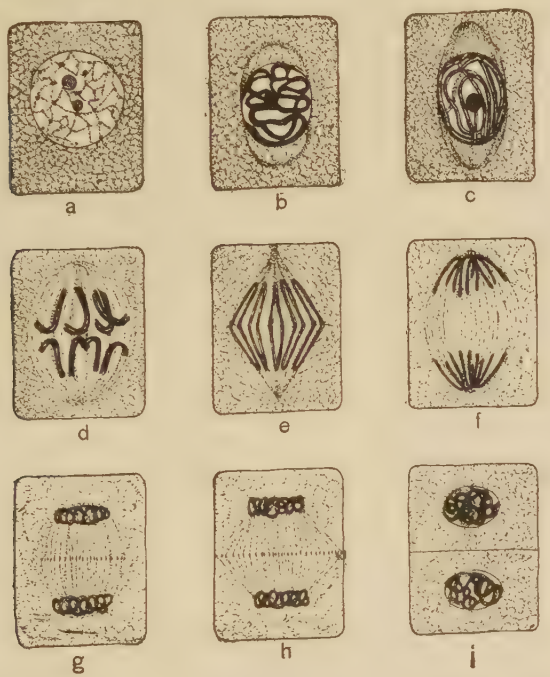


FIG. 281.—Illustrating the several stages of nuclear and cell-division. *A*, Resting cell ready to begin division. *b*, *c*, *d*, *e*, *f*, *g*, *h*, showing the deep seated changes that take place within the nucleus during the process of cell-division—reproduction. *i*, The two daughter cells are now ready to grow to the size of the parent cell in *a*, when the daughter nuclei will appear as does the nucleus there. All highly magnified. (*From Stevens' Plant Anatomy.*)

The Cell and Its Relation to the Plant.—If a plant or an animal grows, it is able to do so because the individual cells of its body are able to grow and reproduce themselves. If a wound heals, it is because the neighboring cells reproduce themselves and replace the destroyed tissues with new. If a plant respires, it is because every living cell in the plant body respires. A plant requires food and water because of the needs and requirements of the cells. A condition of health on the part of the plant is a condition dependent upon the health of the cells that compose the plant. If the conditions surrounding the root hairs of a plant are unfavorable to their existence, the plant

suffers accordingly. In short, the vital activities of a plant or an animal are an expression of the activities taking place in its cell structures.

The Need of Water.—Protoplasm may be kept alive even though very dry, as is the case in dry seeds. In the dry state protoplasm is inactive (dormant) and exhibits none of the characteristics of a living substance. In order for protoplasm to be the most active it must have sufficient quantities of water to keep it in a fluid condition. Since the cell wall that confines the cell contents has no openings that are large enough for the entrance of solid materials, only those foods freely enter that are in solution in water. Since only the soluble foods are able to pass through the cell wall, water serves as the transporting agent for the nutritive materials of the cell. Without such a transporting agent, cells are unable to receive foods or distribute these materials within themselves. In plant tissues water transports the soluble materials from cell to cell and thus from one part of the plant to another.

Root-hairs.—In order that plants may be provided with sufficient quantities of water they have found it necessary to

FIG. 282.—Diagram to illustrate root-hair *h* in the soil, and its relation to the soil particles, the capillary film of water *w*, and the air spaces *a*; *e*, epidermal cell of the root, of which the root-hair is an outgrowth, or branch. (*From Gager's Fundamentals of Botany.*)

provide themselves with special absorbing organs for the intake of soil waters. Under average conditions the water in the soil exists as a thin film of moisture around each soil particle and

grain of sand. This film of moisture holds in solution a very small amount of soil salts that are necessary to the growth of plants. To gather the films of moisture about the several soil particles it is necessary to have a great number of fine root structures reach out in every direction and immerse themselves in the films of water (Fig. 282). As the young root extends itself through the soil, some of the epidermal cells bulge out their cell walls and form slender tubes known as *root-hairs*.

The root-hair continues to grow until it strikes a soil particle, when it bends about and flattens itself upon the surface of the grain of soil. The root-hair robs the particle of its moisture and transports the water to the inner cells of the root—to the endodermal cells (Fig. 283). The endodermal cells deliver the collected water to the vascular cells (xylem group in Fig. 283), which transport the crude soil waters upward through the root and stems to the leaves. In the leaf the crude soil waters and carbon dioxide are acted upon by the chloroplasts and sunlight, and changed to foods. The foods thus made in the leaf are transported to roots by a second system of vascular bundles (phloem group in Fig. 283). Thus before the crude soil water is of service to the root and its root-hairs, it must be manufactured into food materials.

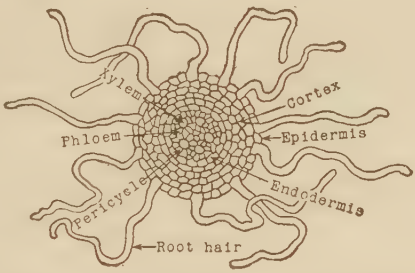


FIG. 283.—Cross-section of a root in the region of the root-hairs. (*From Stevens' Plant Anatomy.*)

Osmosis.—Since the root-hair is surrounded by a cell wall with no apparent openings, the question arises: "How do the soil waters with their dissolved materials enter the root-hair?" When a lump of sugar is placed in the bottom of a glass of water, the water surrounding the lump quickly becomes filled with dissolved sugar. When a quantity of the water about the lump of sugar is removed with a medicine dropper and touched to the tongue, it tastes sweet. Even though we carefully avoid stirring the water or otherwise disturbing it, we shall find after a time that the dissolved sugar has spread through the whole

body of water. Thus the dissolved sugar is able, by its own motion, to pass from place to place within the body of water contained in the glass. This act on the part of dissolved substances to distribute themselves everywhere through a liquid is known as *diffusion*.

The process of diffusion occurs between liquids that are soluble in each other, between liquids and soluble solids, between liquids and soluble gases, and between gases. When we see the smoke and gases arising from the chimney of a home or a factory, we know that the escaping gases are everywhere spreading themselves throughout the air—diffusion of gases is taking place. The oxygen of the air is somewhat soluble in water, and when in solution diffuses itself throughout the entire body of water, for otherwise fish would find it impossible to exist in lakes and oceans.

When two liquids of different densities, such as fresh water and salt water, are separated by a porous membrane, we find water passing through the membrane into the salt solution. In this case before diffusion could take place the water must pass through a porous membrane. This particular kind of diffusion is called *osmosis*. Hence *osmosis* is defined as *diffusion through a membrane.* A more extended definition defines *osmosis* as *the interchange of two fluids of different densities when separated by a porous membrane.*

The application of the processes of osmosis to the root-hairs in the soil aids us to understand how it is possible for these organs to collect the soil waters of the earth. (See laboratory studies "Osmosis" and "Root-hairs and osmosis" introducing this chapter.) The soil water, being a very weak solution of various materials dissolved from the soil, is not so dense as the heavy fluids within the walls of the root-hair. Under these conditions the soil water passes through the membranous walls of the root-hair and collects in the vacuoles within the cell. Since the fluids within the root-hair are always taking up water, they are less dense than the fluids in the cells located within the root. Hence osmosis takes place between the fluids in the root-hair cell and the inner cells of the root. Thus from cell to cell the water is passed to the internal structures of the

root. No process within the plant or animal body is more important than osmosis. Upon it depends the life and death of every living thing.

Transplanting.—Many times it becomes necessary to remove growing plants and replant them in other places. During the removal and the transfer of the plant much care is necessary in order that too great amounts of soil be not removed from the roots. Root systems exposed to the drying effects of the air shrink and harden and when transplanted recover with difficulty. Trees and shrubs are often removed with large quantities of earth in order that the root system and the plant may

FIG. 284.—Showing proper and improper methods of setting plants when transplanting. *A*, Plant set too deep. *B*, Plant set too high. *C*, Plant carelessly set with roots bunched. *D*, Correct setting of plant with regard to both depth and arrangement of roots.

suffer as little shock as possible. When trees and shrubs are sent long distances, most of the dirt about the root system is removed. When this is done, the roots should be well bound with damp mosses and cloth materials. When proper methods are employed, most plants recover quickly from transplanting processes.

In a temperate climate it is quite necessary that some crops be started in hot beds and cold frames long before the outdoor conditions are favorable to the germination of seeds and the growth of the plants of the desired crop. For this reason tomatoes, cabbages, many kinds of flowering plants, etc., are germinated and partially developed in hot beds, hot houses, planting boxes, and pots, and then with the arrival of the proper season they are transplanted in gardens and open fields.

When we transplant, the receiving pits should be dug and properly prepared before the plants are dug up. The holes

should be dug more deeply than required and then refilled to the proper depth with well-prepared loam. The plant should be set squarely in the hole, and its roots spread out in several directions upon the floor of the pit. Loam or well-prepared soil is laid over the roots, and the pit filled slightly above the level of the surface of the surrounding earth. Sufficient water to saturate all of the earth in the pit is slowly added. If the water settles the earth about the plant to a level lower than that of the surrounding surfaces, more earth is added until all surfaces are level. Since the root system requires a period of time (several days in the case of small plants to several weeks with trees) to become again normal, it is necessary to remove a greater or lesser portion of the branch and foliage system in order that the remaining branches and buds may receive the proper amounts of food materials (Fig. 285).

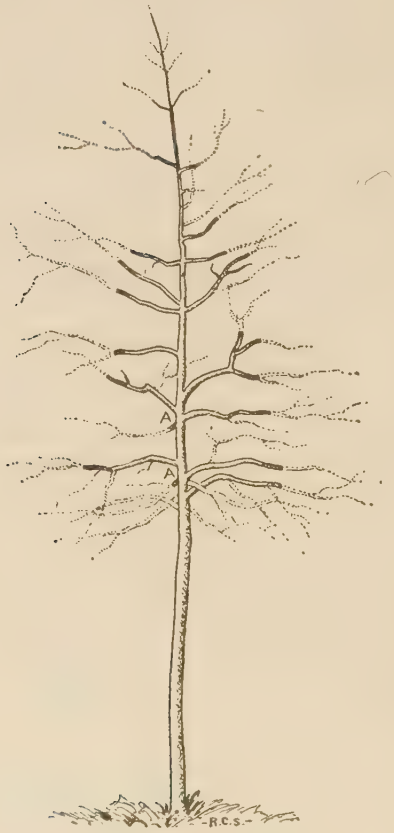


FIG. 285.

The Life of Roots.—The roots that live but one season are *annual*. All of our common cereals—wheat, corn, oats, and rice—have annual roots, as do the common crop plants—tomatoes, peas, etc. The roots of *biennial* plants live through two growing seasons. The common biennials are carrot, beet, parsnip, and cabbage. During the first year biennials store up large quantities of food in their roots (carrot) or leaf (cabbage) structures. These fleshy structures rest over the winter season, and then when the next growing season returns

they send up strong branching stems that bloom and produce seeds. With the ripening of the seeds, the entire plant system withers and dies. Fall wheat is a biennial plant.

The roots of trees and shrubs and of some ferns and herbs live from year to year. These plants are known as *perennial*. The pine, the oak, the maple, the currant, and the wild rose illustrate this great and innummerable class of perennials.

Stems and Their Work.—The first work of stems in trees, shrubs, and herbs is to conduct and distribute fluids throughout the plant system. A second service rendered by the stem is to support the leaves and flowers in positions best suited for the reception of air and sunlight. Thirdly, stems serve as a storehouse for the storage of foods and water. And fourthly, the stem may provide itself with chloroplasts and as a green stem serve as an aid to or a substitute for leaves.

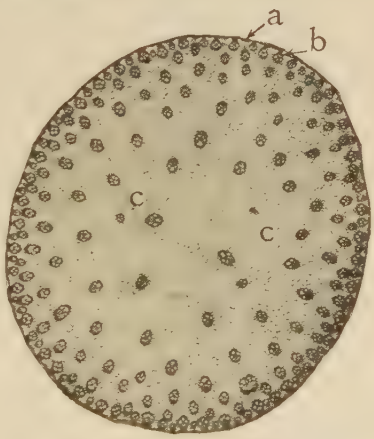


FIG. 286.—Cross-section of a young cornstalk. *a*, Epidermis; *b*, cortex and pericycle; *c*, *c*, pith with vascular bundles interspersed through it—characteristic of monocotyledonous stems. (*From Stevens' Plant Anatomy.*)

Stems and Their Structure. As was already pointed out in the preceding chapter, monocotyledonous and dicotyledonous stems are greatly different in the internal arrangement of their structures (Fig. 269 and Fig. 270). In every-day language the dicotyledonous stem consists of bark, wood, and pith, while monocotyledonous stems are hollow (wheat) or full of pith (corn stem, Fig. 286). In dicotyledons the bark is composed of many different layers (Fig. 287), which are composed of tissues that are adapted to the performance of special labors. The epidermis and layers of cork cells serve as a protective covering and prevent losses of water and consequent drying up. The layers of green cells (the *collenchyma* in illustration) are useful in the manufacture of food. The fibrous cells of the bast tissues give toughness and strength to the stem. The

thin walled tubes that lie between the bast fibers and the cambium layer carry the manufactured plant foods in a liquid form downward to the roots. The cambium layer grows, and on its inner side forms the annual and annular layer of new wood while on its outer side it forms new bark.

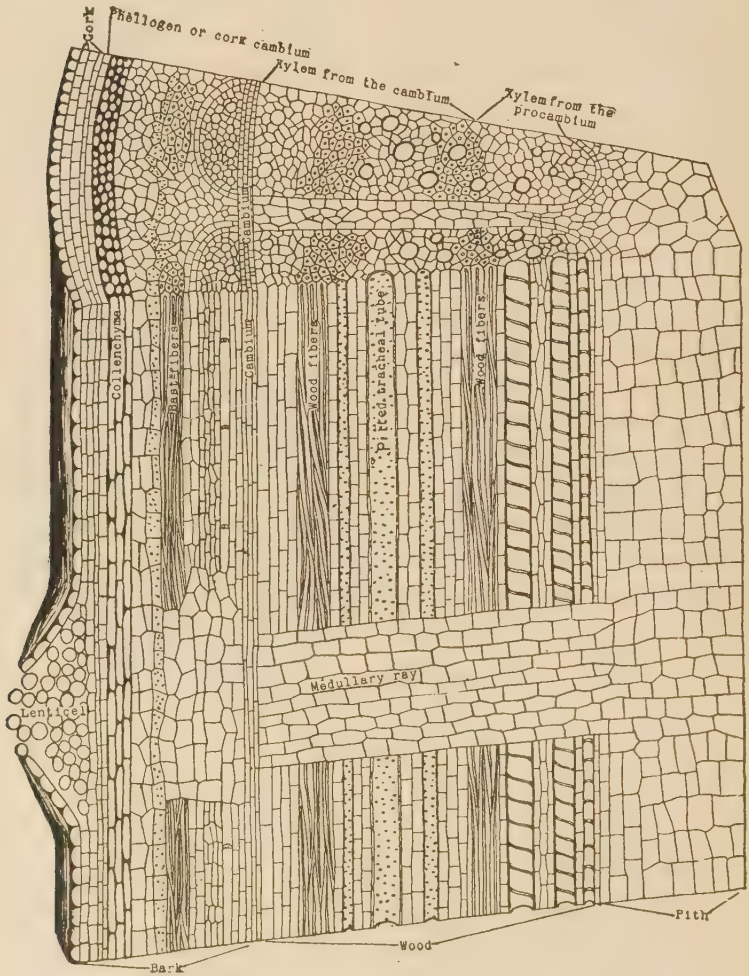


FIG. 287.—Detailed diagram that shows the relationship of the parts and the nature of the structures within a dicotyledonous stem. (*From Stevens' Plant Anatomy.*)

The wood or old cambium portion of the stem is composed of vascular bundles (xylem) that carry the soil waters from the

roots upward or towards the leaves. The fibers which make up a considerable portion of the vascular bundles serve to strengthen and stiffen the stem.

In order that an exchange of gases may take place within the stem structures, breathing organs—the *lenticels*—are provided at various intervals. During processes of growth the stem is using up food materials and oxygen and forming carbon dioxide and other products. The lenticels provide for the intake of oxygen and the excretion of carbon dioxide.

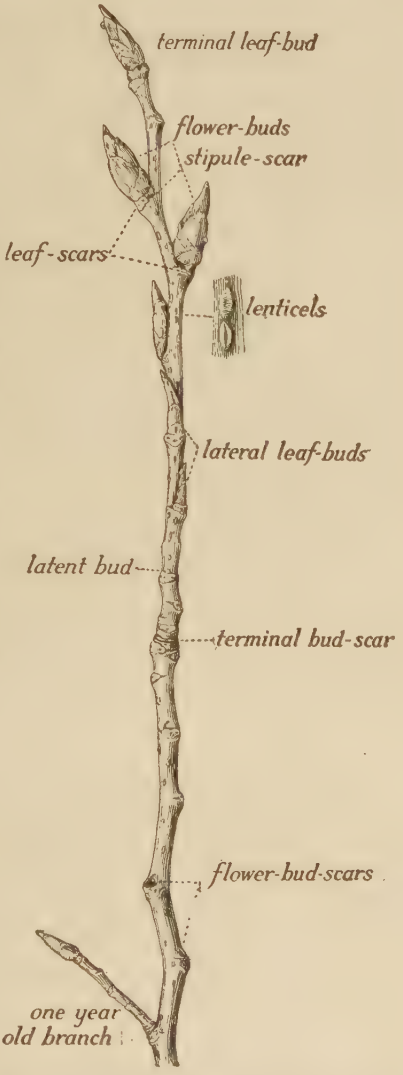


FIG. 288.—Cottonwood twig two years old. *After Longyear.* (*From Robbins' Botany of Plant Crops.*)

Stems and Buds.—On opening a bud and examining it very carefully we find that it contains an undeveloped stem with miniature leaves. For this reason buds are defined as undeveloped stems. Buds are classified according to their development as: (1) *leaf*, (2) *flower*, and (3) *mixed buds* (Fig. 288).

The leaf bud contains a shortened stem bearing a number of undeveloped leaves, and thus leaf buds are often called branch buds. Flower buds contain one or more miniature flowers. It is not always possible to distinguish a flower bud from a leaf bud. In some cases they have different shapes (as shown in Fig. 288), or certain positions upon the stem, or "spurs" that

branch from the stem. Mixed buds contain both leaves and flowers, as is the case in apple buds located at the ends of short spurs.

Buds may be classified as to their position on the stem as: (1) *terminal*, (2) *lateral*, (3) *accessory*, (4) *latent or dormant*, and (5) *adventitious*.

Most stems terminate in a leaf bud. This *terminal bud* is usually the most vigorous on the stem, and therefore succeeds in lengthening a shoot to a greater degree than does a lateral bud. Lateral buds are formed in the axils of leaves and give rise to flowers or to leaves and branches. The accessory buds are the extra and smaller buds that appear on either side of the lateral bud. Accessory buds occur regularly on the maple and the box elder.

Latent buds like lateral buds arise in the axils of leaves, but unlike the lateral buds they do not develop. They may, indeed, lie dormant for years and be completely overgrown in succeeding years before being called into activity. Injury by frost or excessive heat and drought may kill the regular buds of a plant. In such an instance the plant develops its dormant or latent buds. The sprouts that spring from the stumps of felled trees develop from latent buds. Adventitious buds may occur on any part of a plant. They usually appear where injury to the plant has taken place. When branches are cut back, great numbers of adventitious buds develop about the edge of the wounded area.

The Structure of the Leaf.—In order to appreciate the importance of a green leaf and the work that it performs, one should examine its various tissues under the microscope. When pieces of epidermis are removed from the upper and lower surfaces of a leaf and examined, they are found to be made up of a layer of transparent cells wonderfully arranged. The epidermis removed from the lower surface is penetrated with numerous pores—the stomata (Fig. 278 and Fig. 289)—which allow the outside air free access to the air spaces within the leaf, as well as provide for the escape of water and waste products.

Between the two layers of epidermis are located the cell structures that make up the *mesophyll* (*meso*, middle; *phyll*,

leaf) of the leaf. The mesophyll consists of elongated cells arranged in ranks and therefore called the *palisade cells*. Under the palisade layers there is a lower spongy layer of cells that are not so well arranged and are more or less surrounded with air spaces that communicate with the stomata in the lower epidermis.

The cells in the mesophyll contain numerous minute green granules embedded in the protoplasm. These granules are called *chloroplasts*, which have already been described under plastids (this chapter). The material that colors the chloro-

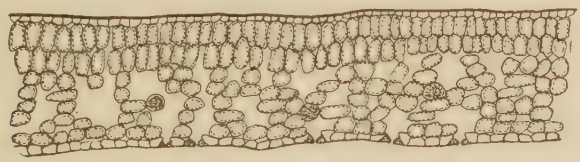


FIG. 289.—Cross-section of a typical leaf. Five stomata are shown in the lower epidermis. (*From Hamaker's Principles of Biology.*)

plasts green is known as *chlorophyll*, which gives the leaf its characteristic color. The chlorophyll may be extracted from the green tissues by warm alcohol, in which it is soluble, the alcohol becoming green and the chloroplasts colorless.

The functions of the various parts of the leaf have been partly set forth in the laboratory work introducing the chapter. More concerning the functions of the various parts of the leaf will be given in the following topics.

Plants and Their Food Problem.—A grain of corn contains a supply of starch, proteins, and oil for the young plant. These food materials are just as essential to the plant after the processes of germination have taken place as before. Now the mineral soils and the air do not contain any of the complex food substances—carbohydrates, proteins, and oils. Yet the green plant grows luxuriantly on mineral soils and air, and builds up a plant body that consists of these materials. Since the plant is fixed for life to a certain spot and cannot go in search of foods as animals do, the plant must be able to manufacture the required foods from the simpler substances found in the soil and the air. Careful and thorough studies have

established the fact that the green cells of plants are able under certain conditions to manufacture certain simple substances found in the soil and air into complex food substances. Since the green cells occur only in the leaves and stems of plants, it is these organs that serve as the manufacturing establishments in green plants.

Photosynthesis; Manufacture of Starch.—When we visit a factory in which raw materials are being manufactured into finished products, we see pipes, trucks, and conveying machines bringing the raw materials into the factory. We observe the forces derived from steam and electricity at work driving and turning the mills and various devices that transform and convert the crude products into finished products. We note another set of pipes or conveying machines at work removing the manufactured materials and storing them away in storerooms until needed on the market. When we complete a tour of inspection of such a factory, we are usually able to see the factory as a unit composed of wonderful engines and machines for the purpose of changing certain selected raw materials into certain finished products and by-products.

The leaf is nature's factory in which all the foods of the plant and animal world are first prepared. The raw materials of this factory are carbon dioxide of the air and the soil waters gathered by the root-hairs. The finished products are starch and plant sugar, and the by-product is oxygen gas. The chloroplasts are the machines that harness the sunlight to the process of making starch. The veins—vascular bundles—and the stomata deliver the raw materials, carry away the manufactured products, and release the by-products. The essentials named above compose the working parts of nature's mill. This mill seems very simple in a way, yet, as we shall see, it is more wonderful than any mill yet made by man.

In some manner, not yet known, the chloroplasts are able to combine carbon dioxide and water and the energy of sunlight into complex particles of starch and free oxygen. The most wonderful thing about the chloroplasts is that they are able to stow away the energy of sunlight in the particles of starch. When plants and animals use the starch as food, the stored-up

energy is released as heat energy. Since sunlight is absolutely essential to the manufacturing process employed in the leaf, this method of making starch from carbon dioxide, water, and sunlight is known as *photosynthesis* (Greek: *photos*, light; and *synthesis*, putting together).

During the hours of sunlight the process of photosynthesis goes on at such a rapid pace that the leaf structures become filled with starches. In order to remove the insoluble starches,

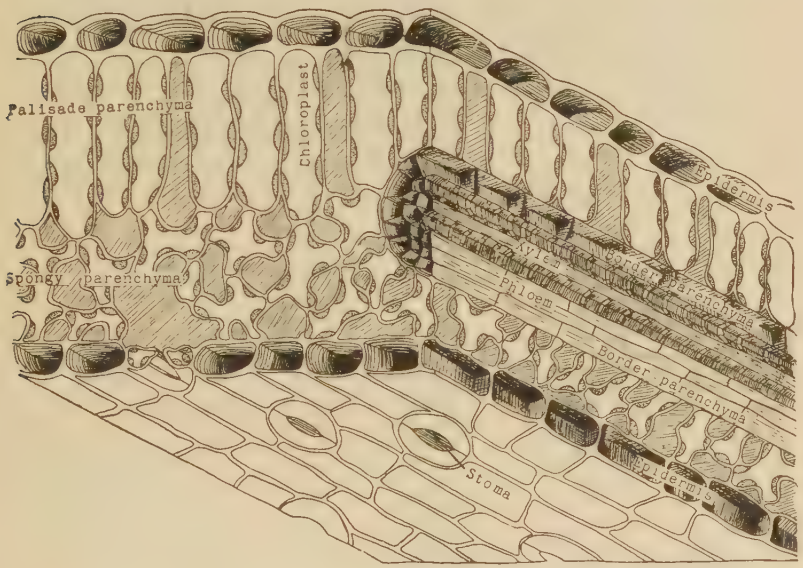


FIG. 290.—Diagram to show the architecture of a typical leaf. (*From Stevens' Plant Anatomy.*)

enzymes in the protoplasm change the starches to soluble sugars. The sugars are collected by a special vascular system (phloem in Fig. 290) and moved into the stem and root, where they may be stored or distributed for purposes of growth and repair. During the hours of the night there is, of course, no photosynthetic process taking place, and thus during the hours of darkness the starches and sugars are more or less completely removed from the leaf. With the return of daylight the cells of the leaf are free of obstructing foods and in good condition for continuing the manufacturing of more starch.

The Production of Fats and Proteins.—In addition to carbohydrates, plants require fats and proteins. The fats and oils

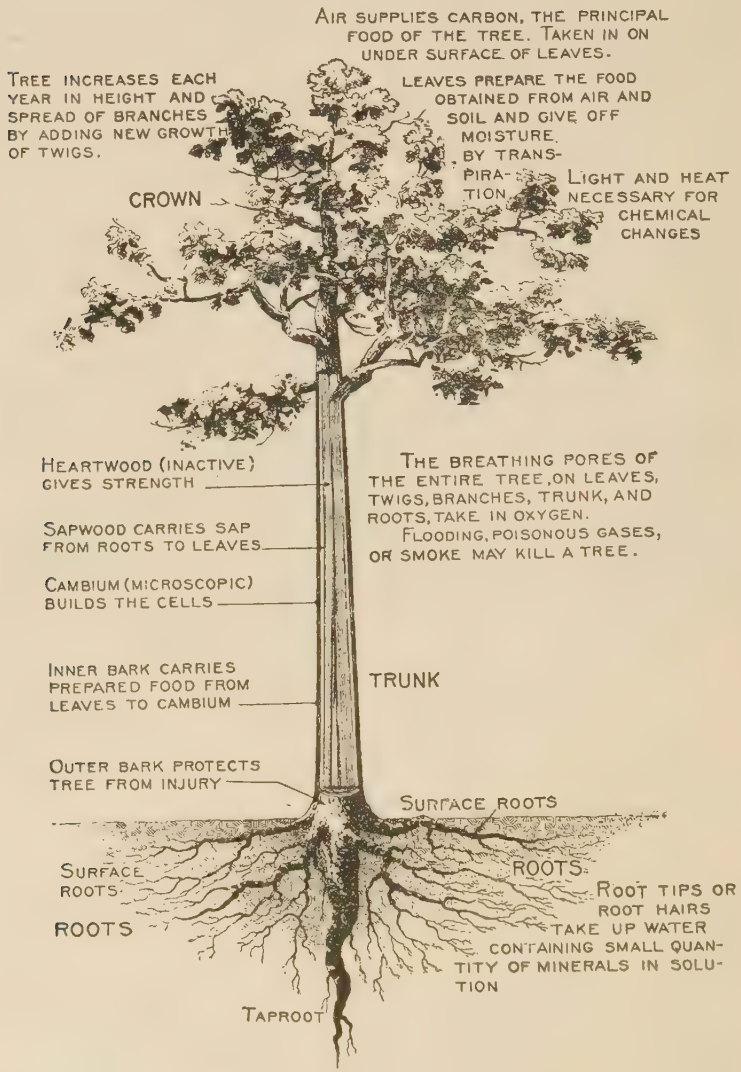

AIR SUPPLIES CARBON, THE PRINCIPAL FOOD OF THE TREE. TAKEN IN ON UNDER SURFACE OF LEAVES.
TREE INCREASES EACH YEAR IN HEIGHT AND SPREAD OF BRANCHES BY ADDING NEW GROWTH OF TWIGS.
LEAVES PREPARE THE FOOD OBTAINED FROM AIR AND SOIL AND GIVE OFF MOISTURE, BY TRANSPIRATION.
LIGHT AND HEAT NECESSARY FOR CHEMICAL CHANGES
CROWN
HEARTWOOD (INACTIVE) GIVES STRENGTH
SAPWOOD CARRIES SAP FROM ROOTS TO LEAVES
CAMBIUM (MICROSCOPIC) BUILDS THE CELLS
INNER BARK CARRIES PREPARED FOOD FROM LEAVES TO CAMBIUM
OUTER BARK PROTECTS TREE FROM INJURY
THE BREATHING PORES OF THE ENTIRE TREE, ON LEAVES, TWIGS, BRANCHES, TRUNK, AND ROOTS, TAKE IN OXYGEN. FLOODING, POISONOUS GASES, OR SMOKE MAY KILL A TREE.
TRUNK
SURFACE ROOTS
SURFACE ROOTS
ROOTS
ROOTS
ROOT TIPS OR ROOT HAIRS TAKE UP WATER CONTAINING SMALL QUANTITY OF MINERALS IN SOLUTION
TAPROOT

FIG. 291.—Structure of tree, and functions of its parts. (*From Brownell's General Science.*)

are composed of the same elements—carbon, oxygen, and hydrogen—as the carbohydrates but in different proportions. The

proteins contain carbon, oxygen, hydrogen, and nitrogen. The fats are produced from the carbohydrates by certain enzymes that occur in the protoplasm. The manufacture of proteins occurs largely in the protoplasm of the leaf cells, where carbohydrates and a solution of nitrates from the soil are made to combine so as to result in protein foods.

Respiration.—The object of respiration is to furnish oxygen to the cell and to remove carbon dioxide from it. The assimilation of oxygen and the excretion of carbon dioxide take place in the cells of an organism as a part of the process of nutrition. Without a constant supply of oxygen and an equally constant removal of carbon dioxide, the changes which give rise to conditions favorable to life could not be maintained. The absorption of oxygen is just as necessary as the digestion and absorption of a protein or other food. The absorbed oxygen and the digested foods are brought together in the protoplasm of the cell for the purpose of producing oxidation. Oxidation is accompanied by the production of heat. Since the cell needs a continuous supply of heat, oxidation is a continuous process within the cell. Since oxidation is continuous, the formation of waste products is also continuous. In all plant and animal oxidations, carbon dioxide occurs as one of the waste products. A cell must be provided with means that will serve it with constant supplies of oxygen and with the constant removal of carbon dioxide. The process that secures these means to the cell is called *respiration.*

Photosynthesis versus Respiration.—Within the living cell structures of a growing plant, the process of respiration is continually taking place. Throughout the day and night the plant cells require constant supplies of oxygen and the constant removal of carbon dioxide. The entrance of oxygen and the exit of carbon dioxide through the stomata and the lenticels are continuous in order that the process of respiration may maintain the necessary oxidation processes so necessary to the plant cell.

During the hours of daylight the process of photosynthesis is taking place in the leaf organs. Since photosynthesis takes place more vigorously than does the process of respiration, the plant returns more oxygen to the air than it uses, and absorbs

more carbon dioxide than it excretes. That is, during the hours of daylight a green plant is actually enriching the air with supplies of oxygen while removing greater quantities of carbon dioxide than it respires. It is an error to think that the processes concerned with respiration are not in action when photosynthetic processes are in operation.

TABULATED CONTRASTS OF PHOTOSYNTHESIS AND RESPIRATION

Photosynthesis	Respiration
1. Occurs only in plant cells containing chlorophyll.	1. Occurs in all of the living cells of plants and animals.
2. Operates only in the presence of sunlight.	2. Operates continuously.
3. Absorbs carbon dioxide.	3. Sets carbon dioxide free.
4. Sets oxygen free.	4. Absorbs oxygen.
5. Constructs carbohydrates.	5. Oxidizes carbohydrates.
6. Stows away light and heat energy in the form of potential energy.	6. Sets heat energy free which becomes energy of motion—kinetic energy.

Digestion and Assimilation.—It has already been pointed out that the protoplasm of a cell has the power of building up living materials which are in every way like itself. Now before foods can be converted from non-living matter into living matter, the foods must undergo such changes as will make them suitable for reception into the living body of protoplasm. These changes are brought about by two processes—*digestion* and *assimilation*.

Since protoplasm can not make use of solid or insoluble foods, all foods that are to nourish it must be converted into soluble substances and brought into solution. *The process of changing an insoluble food into a soluble one and bringing it into solution is digestion.* The process of digestion is brought about by digestive ferments or enzymes that have the power of acting on insoluble carbohydrates, proteins, and fats, and bringing them into solution.

Although the foods are in solution and within the cell wall, they are no part of the living protoplasm of the cell. The

dissolved foods are simply in solution in the cell—that is, in the sap that lies within the vacuoles. One more event must take place—*a conversion of soluble and non-living matter into living protoplasm.* The process by which this wonderful change is brought about is called *assimilation,* which is simply defined as *the process through which protoplasm transforms nutritive materials into new protoplasm.* Nothing is known about the actual details concerned in the process—the transformation.

Assimilation and Dissimilation.—No sooner is new protoplasm built up by the process of assimilation than it begins to dissimilate, to form other substances—cell-walls, plastids and coloring materials, gums, poisons, perfumes, enzymes, and a thousand and one substances essential to the cell or tissue in which the protoplasm exists. *The process by which protoplasm forms materials out of its own substance is known as secretion.* Hence in the body of the protoplasm two processes are always at work—assimilation, which is concerned with the formation (construction) of protoplasm; and secretion, which is concerned with disintegration (destruction) of protoplasm. To the sum total of all these changes—assimilation, secretion, or excretion—the term *metabolism* is applied.

So long as the cell, the tissue, the organ, the plant, or the animal is able to assimilate enough to supply the deficit caused by the destruction of material, the organism will live; but when the intake cannot make up for the output that is lost, the organism ceases to act, and this is called *death.* Continuance of life demands a balance between assimilation and dissimilation. Growth demands an overbalance in favor of assimilation. Decay means an overbalance in favor of dissimilation.

Projects

1. To learn how to transplant trees in order to plant a shade tree or a fruit tree.
2. To learn how to select, transplant, and care for a vine for the purpose of screening, shading, decorating, producing flowers or fruit.
3. To learn the art of grafting and budding trees and plants for the purpose of putting the art to practical use.
4. To learn how to obtain new plants from cuttings and slips removed from other plants.

5. To make a study of insect foes of plant life and to learn the best means of combating them.

6. To make a study of bird life in relation to food production.

7. To make a report on the life and work of Luther Burbank.

8. To conduct a campaign against the presence of noxious weeds in the community.

9. To make a study of the culture of the sugar beet and its relation to the nation's supply of sugar.

10. To make a collection of the various foods that are prepared and manufactured from corn.

11. To conduct a campaign for securing means and plans for beautifying the city's streets and boulevards with shade trees.

12. To form a boy's agricultural club for the purpose of raising select crops and awarding competitive honors.

13. To form boys' and girls' garden clubs for the purpose of awarding honors to those who attain the best results.

14. To learn the best methods of preparing, planting, and maintaining lawns in order to become an expert care taker of the home lawn.

15. To form an arbor and bird club and to prepare and give appropriate programs for the purpose of creating public interest in the conservation of birds and trees.

16. To prepare for the press articles relative to the conservation of trees and birds.

In many of the above cases the information may be secured from: The United States Department of Agriculture, Washington, D. C. Experimental Stations conducted by the state. Agricultural Colleges and the International Harvester Co., Chicago.

CHAPTER XXIII

THE FLOWER AND ITS FUNCTION

Object.—To make a study of the uses of flowers to plants and their special fitness to the performance of these labors.

The Need of Flowers.—During the first period of its life a flowering plant is occupied with the development of its roots, stems, and leaves. The roots, the stems, and the leaves are specialized organs for the gathering, or the distributing, or the manufacturing of food materials. In the oak the root-hair cells, the guard cells of stomata, the cells of the vascular bundles, and the cells of the cambium layers and other tissues are all highly specialized groups of cells well fitted for the performance of special kinds of labors. Each group performs a labor which is necessary to the existence of the plant. The sum of all the special labors enables the plant to live successfully. In short, *the plant is the result of the organized labors of its many specialized tissues.*

We learned, furthermore, that growth in the plant is the result of cell-division and cell-growth. Before a plant can increase in size, extend a root, develop a bud or any other part of itself, cell-division and cell-growth must take place. Hence, a plant grows, because its cells are able to reproduce cells like themselves. This method of reproducing cells—cell-division—occurs in all living organisms. This kind of reproduction does not result in the production of a new oak or a new corn plant. In order to produce a new oak, a different process is required. Not only is this true of plants, but of all the many celled organisms—insects, fish, birds, and animal forms of every kind. Since the method of reproduction in flowering plants is essentially like that in all other higher organisms, the process of producing seeds (baby plants with supplies of food) by means of specialized structures called flowers is the theme of this chapter.

THE FLOWER

Object.—To make a study of the various parts of a flower and the nature of the special labors performed by each.

APPARATUS.—Microscope. Magnifying glass. Glass slide. Cover glass. Needle. Three watch glasses (bell jar on dinner plate—one per class).

MATERIALS.—Typical flowers—geranium, tulip, lily, spring beauty, apple, or others according to the season. More or less modified flowers—sweet pea, nasturtium, butter and eggs (toad flax), snap dragon, and others. Stock bottles containing 10%, 5%, and 3% solutions of cane sugar.

PROCEDURE AND OBSERVATION.—1. Select a flower from a geranium, plum, apple, or simple flower. Observe the arrangement and relationship

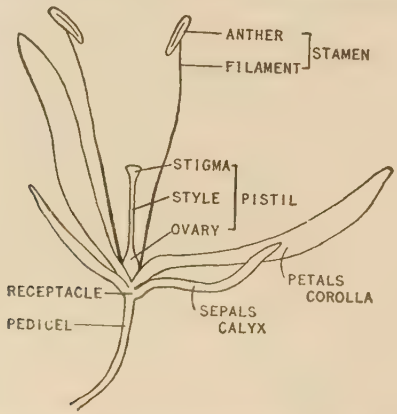


FIG. 292.—Diagram of a typical flower, its parts and their subdivisions. (*From Atwood's Civic and Economic Biology.*)

of the several parts and obtain their names by consulting Fig. 292 and Fig. 293.

The head of the *pedicel* or stem forms the *receptacle.*

All *sepals* taken together form the *calyx.*

All the *petals* form the *corolla.*

Compare the color of the corolla with that of the calyx in several flowers. Of what service is the calyx to the flower when in bud and in bloom? Of what purpose is the corolla? Consult the text.

2. Examine the stamens, their filaments and anthers. Are all of the anthers dry and much withered, or full of ripe pollen that drops from the anther, or green (unripe) and swollen with no escaping pollen?

Dust some pollen onto a glass slide and examine with the microscope. Observe the many projections on their surfaces.

(The following portion may be prepared beforehand in order that work may be completed the same day.)

Prepare three watch glasses: the first partly filled (¼) with a 10% solution of cane sugar; second, 5%; and third, 3%. Dust the pollen from

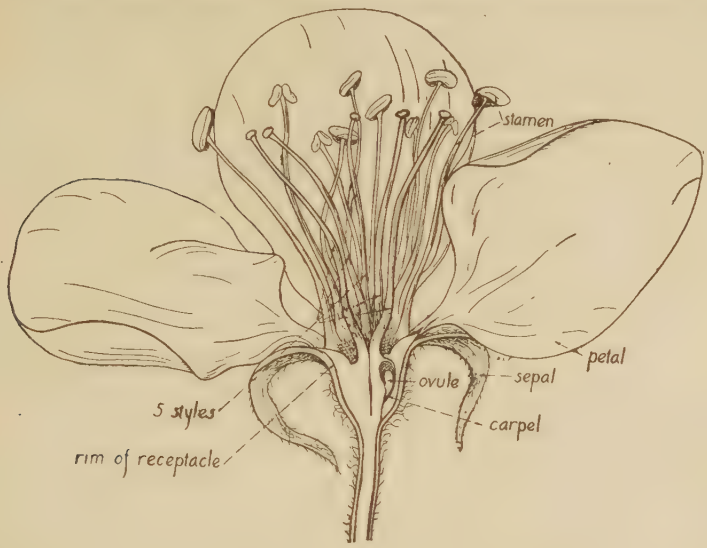


FIG. 293.—Apple, lengthwise section of flower. The ovary is divided into five sections, hence the five styles and stigmas. (*From Robbins' Botany of Crop Plants.*)

several varieties into each of the three solutions Place the three preparations under a bell jar that stands on a plate or glass. A dampened sponge should be placed within the bell jar.

After 24 hours examine the pollen grains under the microscope and observe whether they have developed pollen tubes (see Fig. 294).

Has the sugar solution served as a food to the pollen grain? Can you understand why the stigmas of flowers are often found covered with secretions of plant sugars (see Fig. 297)?

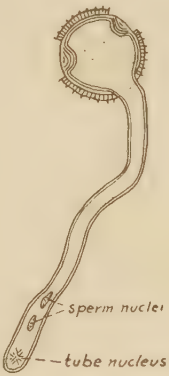


FIG. 294.—The pollen grain developing the pollen tube. Highly magnified. (*After Bergen and Caldwell.*)

3. Remove the pistil from some large flower—tulip or lily. Examine the stigma with the magnifying glass. Is it well adapted for receiving and holding pollen grains? Brush the stigma against some of the ripe anthers. Does pollen adhere to the stigma? If a bee or a current of air laden with pollen grains should happen to come into contact with the stigma, is there a possibility of pollen being transferred to the stigma (Fig. 300)? What is meant by pollination?

Cut the ovary crosswise and one of the portions lengthwise. How many compartments or divisions do you observe? Are there few or many ovules in each compartment? Examine the ovaries of young flowers and of old or wilted flowers. In which case are the ovules the more developed? What must take place before an ovule can develop into a seed (see Fig. 297)?

4. (*a*) Make a drawing (Fig. 292) of the flower that you have studied. Letter and name the parts and their subdivisions.

(*b*) State briefly the work or the function of each part.

(*c*) What is the purpose of the flower?

(*d*) Define the terms pollination, fertilization, self fertilization, and cross fertilization. Consult the text of this chapter.

POLLINATION (FIELD TRIP FOR INDIVIDUAL OR GROUPS)

Object.—To make a study of the several kinds of flowers as they occur in nature for the purpose of observing the methods and the means employed for securing the pollination of the stigmas.

Apparatus.—Magnifying glass. Needle.

Procedure and Observation.—1. If fruit trees are in bloom, observe the bees at work. Observe how the bee alights upon the flower. What is the purpose of the bee's visit? Is it possible that his body may become covered with pollen dust (grains)?

2. Why is the corolla colored? Does the bee alight on the corolla? Where are the nectar glands and the nectar? Why do flowers give off odors?

What is pollination? Cross pollination? Self pollination? What are the advantages and disadvantages of each kind of pollination?

3. While the bee is at work, it is possible to ensnare him with a glass and cover. It is not necessary to kill the bee; study it by observing it through the glass.

The bee's body is divided into three divisions: *head*, *thorax*, and *abdomen*. How many pairs of wings and legs do you observe? To which division of the body are they attached?

Study the mouth divisions. Are they fitted for biting or sucking (see Fig. 300)?

What portions of the body are covered with hairs? Could the hairy legs and body hold and carry pollen from flower to flower—from anther to stigma? Would this act cause cross pollination?

Does the bee serve the flower? Does the flower serve the bee? Release the bee.

4. Continue the observational work with other field flowers. Compare their colors, odors, peculiar shapes (adaptations to insects), arrangement of parts, etc. Are the colored and scented flowers suited to the visits of bees and other insects? Are some better adapted to the visits of insects than others, or are they all equally well adapted but in different ways?

If a flower succeeds in attracting insects year after year, the flower has accomplished its purpose. Success may be the result of different methods.

If possible observe bumblebees at work on snap dragon and red clover blossoms. Which flower has provided the more complicated arrangement of flower parts? Which plant produces the more seeds? Which produces the larger seeds? Which plant is the more numerous? Which one is the more successful?

If possible watch the sphinx moth and humming bird at work upon the flowers of the salvia, nasturtium, and similar flowers that have nectaries located at the bottom of deep corollas and long spurs.

5. Do you observe competition among the various plants when you are studying their flowers?

Do some give more odor than others? Is this an effort to attract insects that might have gone to other flowers of a different kind of plant? Is this an effort to meet and overcome competition?

Do some have more brilliant colors and little or no odor? Is this a competition from the standpoint of color?

Do some have large flowers of brilliant colors accompanied with no odors? Is this another way of meeting competition?

Do some have small flowers with excessive amounts of odor and nectar? Do you think that this method would attract as many bees as bright colors with small amounts of nectar?

Find other forms and variations indicating competition among flowers of plants in their endeavor to attract insects.

6. Observe the flowers of maples, box elders, willows, poplars, and similar early flowering trees.

Why is it that these flowers have no odor, no nectaries, no large corolla with bright colors? Why is it that they have a great number of stamens that yield large quantities of pollen? Do they make use of the bee or the wind to transfer their pollen from anther to stigma? If the wind carries the pollen is there any need of competition? Explain. Why need there be such an abundance of pollen when the winds act as a carrying agent? Is there a waste of pollen?

Which is more expensive to the plant —(1) an abundance of pollen with no brilliant corolla, no nectar, no odor—or (2) little pollen with nectar, odor, and corolla?

Are both methods successful? Give instances supporting your answer.

Why are plants so concerned that pollination shall take place?

Is pollination an essential process? If pollination were prevented, what would be the vital result? What plants would suffer the most?

How are wheat, corn, barley, and cane pollinated?

The Flower.—The real purpose of flowers in plants has been known for scarcely more than a century. Previous to this period of time the real mission of flowers and their service to

the plants that bore them were hidden in mystery. Many learned men spent their time studying the forms of flowers, their likenesses and differences, and classifying them into groups and families. But beyond these superficial observations they saw little or nothing. They did not know the purpose of the pollen grain and its relation to the ovule in the ovary. They did not know that the bee and other insects and the winds were

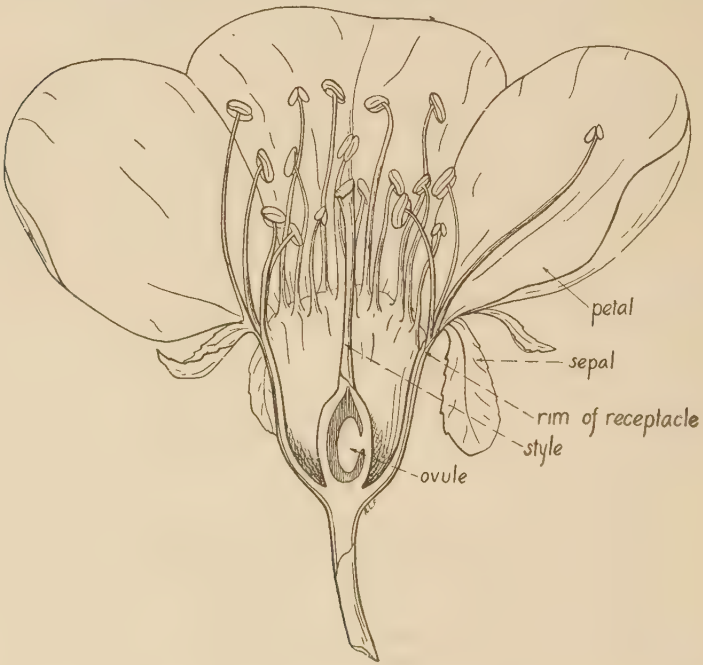


FIG. 295.—Sour cherry, lengthwise section of flower. The stigma mounts the style of the pistil. Many stamens are shown. (*From Robbins' Botany of Plant Crops.*)

the transports of life in the form of pollen grains. They knew that bees gathered the nectar from flowers and stored it away in their hives as honey. But the *reason* why flowers had nectar did not occur to their minds. Before the time of Christian Conrad Sprengel and Charles Darwin flowers were nothing more than botanical specimens. Prior to these men the students failed to read in the flowers the most important message found in all the plant kingdom—a message concerned with the creation of new individuals and the continuance of life.

The Structure of the Flower.—The complete flower consists of six parts—pedicel, receptacle, calyx, corolla, stamens, and pistil. The blossoms of the apple (Fig. 293), the cherry (Fig. 295), and the sweet potato (Fig. 296) represent well the typical forms and the arrangement of the parts of a complete flower. The upper portion of the flower stalk, *the pedicel*, is often enlarged so as to form a *receptacle* which serves as a foundation and a place of attachment for the several organs of the flower. About the outer edge of the receptacle is a whorl of small green leaf-like structures, *sepals*, which form the *calyx*. The sepals of the calyx completely enclose the flower when it is in the bud stage. Just within the calyx is a whorl of more or less brilliantly colored leaves which are the *petals* that make up the *corolla*. The calyx and the corolla are often referred to as the *floral envelopes*, for the reason that they enwrap or envelop the inner organs of the flower.

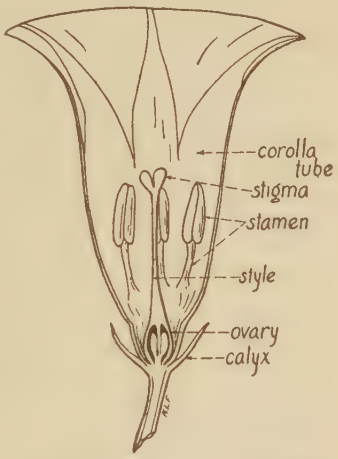


FIG. 296.—Flower of sweet potato, lengthwise section. Same arrangement of parts found in the morning glory, moonflower, cypress vine, and bind weed. (*After Sargent.*)

Within the corolla are the *stamens* with their thread-like stalks mounted with *anthers* which secrete and build up the *pollen* of the flower. The center of the flower is occupied by one or more pistils. The pistil is divided more or less distinctly into three important parts—the *stigma*, the *style*, and the *ovary*. The ovary forms the base of the pistil and contains ovules (or egg-cells), cell-like structures, which will, under given conditions, develop into seeds. The stigma is usually an enlargement of the summit of the style. The surface of the stigma usually secretes a sugary fluid in which pollen grains are received and held during the process of *fertilizing* the ovules.

Pollination and Fertilization.—Before an ovule can grow and develop into a seed, it is necessary that certain vital portions of the protoplasm within a pollen cell be added to that within

the ovule or egg-cell. In order that this condition of affairs may take place, it is first necessary that a suitable grain of pollen be transferred to the stigma. *The act of transferring the pollen to the stigma is pollination.*

When the stigma has received the grain of pollen, the second step in the process takes place. The sugary secretions on the

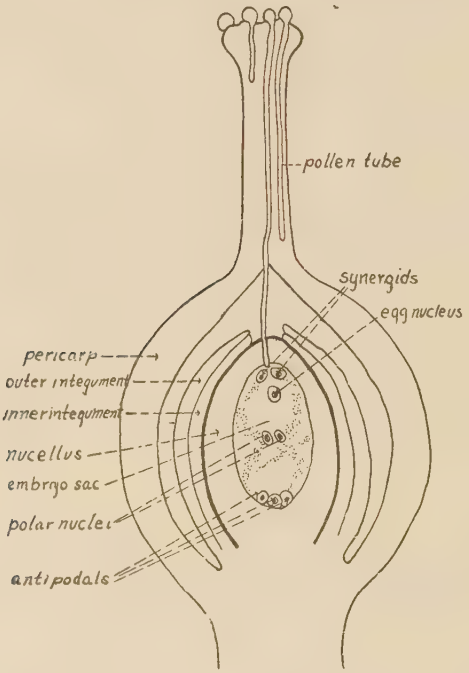


FIG. 297.—Diagram of a simple pistil with pollen grains on the stigma. Three grains are developing pollen tubes. One tube has entered the embryo sac. When the sperm cell of the pollen grain has been delivered to the embryo sac, the act of fertilization has taken place. (*From a Text Book of Botany by Coulter, Barnes, and Cowles. Copyright by the American Book Company, Publishers.*)

stigma awaken the pollen grain to action, and it develops a microscopic tube from one of its sides. The pollen tube pushes its way downward among the cells of the stigma and the style and toward the egg cell in the ovary (Fig. 297). The pollen grains of most plants contain three cells. One of these is concerned in the building and growing of the tube. The other two are the *sperm* cells; and as the tube advances, they travel

through it. Finally, when the tube has extended itself into the ovary, the end of the tube penetrates the cell walls of the egg-cell. As soon as the two sperm cells have passed into the ovule, the opening made by the tube is closed. The contents of the two sperm cells and the egg cell unite and form the *fertilized egg*. The fertilized egg undergoes many deep-seated changes. Cell-divisions take place frequently, and the processes of growth are exceedingly active. The final result is a seed—a young plant enclosed with a quantity of nutritious foods. *The union of a sperm cell with an egg-cell is the act of fertilization.*

Kinds of Pollination.—When a flower is pollinated with pollen from its own anthers or with that from the anthers of other flowers on the same plant, the flower is *self-pollinated*. If the pollen comes from the anthers of flowers on other plants, the flower is *cross-pollinated*. In many flowers it makes no difference whether the pollen comes from the anthers of the flowers on the same plant or other plants of the same kind. In many instances the pollen of plants will not fertilize their own pistils, as is the case with many apples and pears. In Oregon it is found that the Spitzenburg apple requires the pollen of another variety of apple, such as the Baldwin or Jonathan, to fertilize its pistils. Hence in order to insure a crop of Spitzenburg apples, the orchards contain rows of Spitzenburg trees planted between other varieties which bear pollen that is capable of fertilizing the pistils of the Spitzenburg blossoms.

The Sperm and Egg-cell; the Continuance of Life.—As already stated the pollen grain is a mass of highly organized protoplasm that gives rise to the sperm cells (male cells) that unite with the highly organized egg-cells (female cells) to bring about fertilized egg-cells. The sperm and egg are specialized cells whose one purpose is to provide means for reproducing the plant and continuing its life into the future. In order to do this the germ-plasm of a sperm or an egg-cell must contain within itself all the characteristics, all the traits, all the tendencies, and all of the peculiar qualities of the parent plant. In short, *the germ-plasm within sperm or egg-cell is the sum total of all the qualities of the parent plant.* Hence when the germ-plasm of the sperm

unites with the germ-plasm of the egg, the germ-plasm of the fertilized egg possesses all the traits and tendencies of the parent plant to a greater degree than did either the sperm or egg-cell.

From the foregoing we are able, in a measure, to appreciate the special labors that are entrusted to these bits of protoplasm—pollen and ovules as they occur in the flowers of plants. When the pollen grain of a grape flower is transferred to the stigma of a second grape flower, the resulting fertilized egg-cell contains within its germ-plasm the traits and tendencies of the two parent plants. Not only this, but the traits and tendencies of the grandparents and the great grandparents are all continued within the microscopic masses within the fertilized egg. Indeed the traits, the characteristics, the tendencies, and all the potentials of the many thousands of years of the past ancestry of the grape family are continued down through the ages and transmitted by the pollen grains and ovules when uniting to produce fertilized egg-cells. In this manner all organized life persists from generation to generation and thus throughout the periods of time.

Self-pollination and Cross-pollination.—In a cold or wet climate the wheat plant is self-pollinated. Accordingly the fertilized egg consists of germ-plasm that has originated from a pollen grain and an egg-cell of the same plant. In such an instance the fertilized egg has only the tendencies and traits of a single parent plant existing within its germ-plasm. Hence the plants germinating and developing from such seeds will have only the tendencies and traits of the one parent. If the parent plant possesses traits that lead to the formation of large grains packed with a fine quality of starch and protein substances, the plants raised from its seeds may possess these characteristics to a larger degree. Hence if conditions of sunshine, soil, water, and temperature are favorable, the young plants may succeed in producing seeds that are even larger and better supplied than those of the parent plant.

As a rule conditions are not so ideal as outlined above. Often the parent plant acquires weak tendencies and traits that have arisen perhaps from one or many causes, such as plant diseases, unfavorable conditions of food, of moisture, of temperature, or of

sunlight, or any combination of these several factors. And so the seed arising from self-pollination will possess the weak traits of the parent plant and its ancestors to an even greater degree. Continued unfavorable conditions magnify the weak traits in each new generation, until at last the vigor is so reduced that the weaker plants die out.

Durum wheat, however, has the habit of cross-pollinating, and it is proclaimed that this behavior is greatly responsible for its high degree of vitality and vigor, for its wonderful disease-resisting qualities, and for its splendid adaptation to dry climates. In cross-pollination two plants contribute to the germ-plasm within the fertilized egg. The traits and tendencies of two plants are combined in the germ-plasm of the fertile egg-cell. As development of the fertile egg proceeds toward the formation of a seed, the stronger tendencies and traits repress the weaker.

The generation of plants that spring from the seeds of cross-pollinated flowers is provided with all the strong and weak qualities of two parent plants. A plant in the third generation has the traits and tendencies of two parent plants and those of four grandparent plants combined within its germ-plasm. From generation to generation there is a tendency on the part of the incoming and stronger qualities to take the place of the weaker qualities. And thus through cross-pollination each generation of plants is provided with sufficient strong qualities to balance the weaker. Hence, under average conditions of food, moisture, air, and sunlight, each succeeding generation of plants is as strong and successful as its ancestors.

In the case of Durum wheat each new generation is slightly more adaptable and vigorous than its immediate ancestors. This slight improvement of each generation over the last enables Durum wheat to invade more and more the hot and arid regions that are most unfavorable to other varieties of wheat. Hence, during the last 5000 years Durum wheat has spread over the semi-arid regions of Asia that lie between Northern China and Egypt, where, under little or no cultivation, it responds readily and brings forth a fair harvest of grain. For these reasons Durum wheat has been introduced into the semi-arid regions of the West.

Nature's Method of Securing Cross-pollination.—In order that self-pollination may be prevented and cross-pollination be insured, flowering plants make use of various methods for controlling the relationship of the anthers and the stigmas. The two methods most widely used are: (1) that in which the

FIG. 298.—Pistillate and staminate flowers of corn. Cross-pollination is the rule in corn but self-pollination frequently occurs. Wind and gravity are the pollen disseminators. (*From Robbins Botany of Plant Crops.*)

stamens and pistils within a given flower develop and ripen at different times, as in the strawberry and some varieties of plums, (2) that in which the stamens and pistils are set apart in separate flowers, as in Indian corn (Fig. 298) and the field pumpkin (Fig. 299). The flowers containing the stamens

are called *staminate* flowers (male), and those containing the pistils are known as *pistillate* flowers (female). In either method self-pollination is effectively prevented (except Indian corn), and before a fertilized egg can come into existence cross-pollination must take place.

FIG. 299.—The pistillate *A* and the staminate *B* flowers of the field pumpkin. The calyx and corolla have been removed so as to show the essential organs. (*From Robbins' Botany of Crop Plants.*)

Since the plant kingdom has not the power of locomotion (moving from place to place), plants have no means of their own for transporting their pollen from flower to flower. In order to accomplish this transport the plant must make use of whatever agents or forces appear in its immediate neighborhood. A little observation on the part of one who visits the lawn, the flower garden, the orchards, and the wayside fields,

reveals the fact that plants trust their burdens of pollen to such carriers as the wind and insects. While making the above observations one is also forced to take into account the many peculiar shapes, arrangements, colors, and odors of the various kinds of flowers that fit them for the visits of the insects.

Furthermore, while observing insects at work upon the flowers, one is led to but one conclusion—which is, that insects visit flowers for the purpose of procuring food. This is either nectar or pollen, or both pollen and nectar. The nectar is secreted by nectar glands, which are usually located near the base of the flower. Oftentimes the nectar glands are situated in the end of a spur or pouch, as is the case in the nasturtium, the honeysuckle, and the columbine. In this connection it is worthy of notice that the nectaries are so situated that in order for bees or moths to secure the nectar, they are brought into contact with the anthers and stigmas of the flowers.

The efficiency of an insect as a pollinator depends largely upon the nature of its body covering. The bodies of bees, butterflies, and moths are rough with hair or scales, which serve well to hold the pollen while the insect is travelling from flower to flower. Small insects, such as many beetles and ants, which have hard smooth surfaces on their heads, abdomens, and legs, are not efficient distributers of pollen. Thus many plants protect their flowers from the visits of the ant by covering their flower stocks with a downy hair over which the ant is unable to travel.

Flowers like those of roses, poppies, buckwheat, caraway, and numerous others are open to all the flower-visiting insects, and hence are frequently visited by many and all sorts of insects from flies to butterflies and bees. On the other hand, the clovers, the mints, the violet, the snap dragon, and many others have undergone such specialization in their flower structures as to prevent the visits of many insect pollinators. In the snap-dragon and the toad-flax (Fig. 300), the corolla is mouth-shaped and is so firmly closed that it prevents the entrance of small insects. Stronger insects, such as the bumblebee, are able to force the lips apart and thus to enter the flower. In

violets there is much pollen that is hidden deep in the throat of the flower. The tongues of bees are of sufficient length to reach both the pollen and the nectar, which is deep in the spur

FIG. 300.—Sections of flowers of the toadflax. *A*, Front view; *a*, anthers; *s*, stigma; *n*, nectar-gland. *B*, Side view; *o*, ovary. *A* and *B* flowers being visited by insect for nectar. Compare the length of the insect's proboscis with that of nectar-tube. The nectar-gland is at the bottom of the nectar-tube. Note the anthers and stigma rubbing against the dorsal hairs of the insect. *C*, Insect with a mass of pollen. (*From Gager's Fundamentals of Botany.*)

of the corolla. Much in the same way other plants have flowers so specialized that the visits of many insects are shut off.

The bees and other insects are attracted to flowers by means of odors or colors or both. As a result those plants whose flowers have bright colors, much odor, and fair yields of nectar are the more frequently visited by the insect pollinators. And so the

plants whose flowers are the more frequently visited are more certain of success in securing the act of cross-pollination. Hence about us on every hand, we find plants that are the result of the cross-pollinating effects in which insects have made the selection on a basis of flower characteristics.

Wind Pollination.—It has been stated that the wind serves as a transport for the pollen, and, as might be expected, a great number of plants avail themselves of this means. Almost all the grass family, the sedge family, and the pine family (cone-bearing trees) depend upon the wind as their one pollinator. Since the wind is neither guided by color nor directed by odors, it is only now and then that a pollen grain is likely to come into contact with the stimga of the right species of plant. Consequently flowers that have their pollen carried by the wind must produce tremendous quantities in order to increase the chances of having the several stigmas properly pollinated. In this connection it has been estimated that the Indian corn provides anywhere from 40,000,000 to 60,000,000 pollen grains, the number depending upon the size of the plant. In larger plants the number of pollen grains is correspondingly greater, and when one thinks of a pine tree and the quantity of pollen which it must produce, the number of pollen grains is beyond the imagination. Hence wind-pollination appears to be a very wasteful method and expensive to the plant in the way of losses of the very choicest kind of materials that are stowed away in the pollen grain.

Since there is no need of colors, odors, or nectar, the flowers of wind-pollinated plants rid themselves of all unnecessary structures that might hinder the free play of the wind, and thus they consist of only the essential organs—stamens and stigmas. The released pollen is dry and floats through the air like a very fine dust. In order to increase the chances of receiving the pollen from the air, the stigmas are feathery in most grasses, brush-like in the hazel, and thread or silk-like in the Indian corn. In order to reduce the waste of pollen, many wind-pollinated plants develop the flowers before the leaves.

Artificial Cross-pollination.—When a bee visits a group of plants which are in bloom, he flies from flower to flower in

search of nectar; and as a result the several flowers are more or less successfully pollinated. In this instance the pollen of plants with weak traits and tendencies is distributed as freely as the pollen of the plants with vigorous traits and tendencies. Likewise the stigmas of the weak and less vigorous are pollinated along with those that are in every way strong

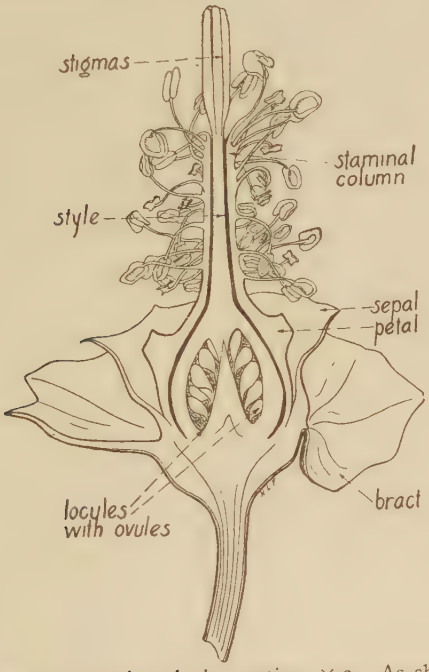


FIG. 301.—Upland cotton, lengthwise section × 2. As shown in the illustration the stamens are attached to a tube that encloses the style and ovary of pistil. (*From Robbins' Botany of Crop Plants.*)

and vigorous. In such a distribution the strong are continually contributing their vitality to the weak and less vigorous. And thus throughout the innumerable generations of plant life, the vital forces of the strong and vigorous are continually battling to raise, or at least to maintain, the average degree of vitality of the plant group to which they belong.

When man takes the plant in hand for purposes of producing food or clothing materials or both, he is not satisfied with average results. Consequently he selects the best possible plants in

order that he may obtain the best possible yields. In dealing with flowers of plants he shuts off the insect pollinator by enclosing the immature flowers of selected plants within a paper bag. When the flower opens, its unripened stamens are removed. The flower is again enclosed. When the stigma ripens, pollen from a selected plant is transferred to it by means of a camels-hair brush. This method of pollinating is known as *artificial cross-pollination.*

The ripened seeds resulting from the act of artificial cross-pollination are planted, and the best plants again selected. Their flowers are artificially cross-pollinated, and the ripened seed is again obtained. The process is repeated until the desired results, or sufficient improvements, have been obtained. By means of artificial cross-pollination Luther Burbank, the Bureau of Plant Industry, and the several Agricultural Experiment Stations have been able to improve many of the agricultural crops and in several instances to produce new varieties of plants.

One of the most important problems for the plant breeder is the production of varieties that are immune to disease. One of the most notable achievements in this direction has been worked out in the Department of Agriculture. The soil of Southern cotton plantations had become infected with a fungus which attacked the roots of cotton plants and yearly destroyed the cotton crop. A survey of diseased areas showed that a few plants had persisted and had blossomed and ripened their capsules of seeds. For several years plants were bred from the seeds of the hardy individuals that had resisted the attacks of the fungus. The result was a disease-resisting variety of sea-island cotton that enabled the continuance of cotton crops in the abandoned areas. The principle of plant breeding and plant selection is not difficult to understand, and no work is more interesting and at the same time more beneficial to humanity than that of plant improvement.

Projects

1. To make a report on the life and work of one of the following: (1) Nehemias Grew, (2) Christian Conrad Sprengel, (3) Carolus Linnaeus, (4) Charles Darwin, (5) Luther Burbank.

2. To make a report on the methods employed by Luther Burbank in bringing about the spineless cactus and the thornless blackberry.

3. To become acquainted with the nature of the work carried on in the Bureau of Plant Industry and to report in detail one or more problems that the bureau has undertaken and solved.

4. To make a report on plant problems that are yet to be solved.

5. To make a study of the bumblebee, or the sphinx moth, or the butterfly, or the humming bird, and its relationship to the flowers of plants.

6. To make a visit to a conservatory for plants in order to make a study of flower forms and special adaptations for securing the visits of insect pollinators. Report the visit in writing. A pencil sketch of one or more flowers should accompany the report.

7. Same as 6 excepting that the visit is made to ponds, or swamps, or woods, or gardens, for the purpose of studying particular flower forms and their adaptation to the visiting insects.

8. To visit an Agricultural Experiment Station for the purpose of observing various methods for plant improvement in actual use. Report in writing.

CHAPTER XXIV

GREEN PLANTS THE MAKERS OF FOODS AND FIBERS

Object.—To make a study of the green plant from the standpoint of its service to man.

The Importance of Plant Materials.—In a preceding chapter we learned that the green leaves of plants were the food makers of the earth. They are to be considered not only the manufacturers of starches, sugars, proteins, and oils, but the makers of such fibers as hemp and cotton. They build the many varieties of woods from which we build and furnish our homes. Furthermore, animals of every form and kind receive their foods directly or indirectly from the plant world. Hence our supplies of milk, butter, cheese, meats, leathers, furs, and many thousands of other animal products are possible only because of the first labors of plants.

An acre of ground that yields thirty-six bushels of corn provides enough food energy to feed 1025 men for one day. The same corn fed to cattle and changed to beef provides enough food energy to supply 45 men for one day, or if changed to pork would supply 225 men for one day. Thus when plant foods in the form of grains are converted to flesh foods, there is a great loss in food energies. In India and China, where the population is very dense, the cereals are the chief foods of the people; in this way they avoid the losses in energy which would take place were the cereals converted to meats. In our country the abundance of the cereal yield in proportion to the population permits us to convert a large portion of it into meats and other nutritious animal products. In short, animal products are converted plant products and hence will be referred to in this relationship.

The importance of plants and animals as producers of food is found in the fact that about 39 per cent (1920) of the population of our country is engaged in agricultural pursuits. This per

centage of our population actually plowed, planted, tilled, and harvested an area of 347,731,000 acres (1919). The total acreage including the grass lands upon which cattle, sheep, and other live stock grazed and fed covered an area of approximately 900,000,000 acres, which consisted of 6,459,988 farms (1920). In short the total food production for the United States is brought into existence through a photosynthetic process working in the green leaves of plants that spring from 900,000,000 acres of farm lands.

The question of food production is a national problem, and since all foods have their origin in the green leaves of plants that spring from the soil, the theme of this chapter is plant life and soil conservation as related to the problem of food supplies.

MARKET REPORTS (HOME PREPARATION)

Object.—To make a study of the market reports as they occur in the daily press.

MATERIALS.—Two or more recent numbers of a daily paper. Scissors. Note book and pencil.

PROCEDURE AND OBSERVATION.—1. Locate in the paper those pages that are given over to the various market reports. Most papers offer a general report on market conditions. Find the report and read it through. Compare the report with that given in the paper the day before or several days before. Do the reports show changes on the market from day to day? Why is this?

Cut out important items and paste them in your note book. Briefly write your comments below the selected items. Continue to select important items and to make comments as you proceed.

2. Locate the "hay and grain" reports. How do the quotations on wheat compare from day to day? Is there a reason why the market should vary from time to time? State the causes.

3. Repeat (2) for corn, oats, rye, and others. Is the general trend of the market up or down?

4. Find the "Cotton Market" report. Read the New York report and compare it with that from New Orleans and Liverpool, Eng. Is the trend of the market "active," "easy," or "weak?" What conditions will produce an "active" market? From the standpoint of the United States is raw cotton an import or an export? Why?

5. Locate the report on the "Coffee Market." Is the market "sharp" or "dull?" Why? Is coffee an import or an export? Explain.

7. Is the market for flour "advancing" or "receding?"

8. How do the Chicago reports compare with those of New York?

9. Find the "Dry Goods Markets." Are "prints" on the trend "up" or "down?" What is the trend of other finished goods? What is the New York report on cotton goods?

10. Report any other reports or market news that you think of particular interest.

BOARD OF TRADE (FOR INDIVIDUAL OR SMALL GROUPS)

Object.—To make a visit to the local board of trade in order to learn how the food, clothing, building materials, etc., are placed before the market and sold.

MATERIALS.—Daily newspaper with the latest market reports.

PROCEDURE AND OBSERVATIONS.—1. Most Boards of Trades have special rulings regarding visitors. Learn what these are and make arrangements accordingly.

2. Usually the operations of the board are mystifying to an onlooker who has never before viewed the trading pit in operation. An inquiry should be made and usually members and friends are willing to point out the details in one or more instances.

3. Of what value is the board of trade to the wheat grower and cattle raiser?

4. Of what value is the board of trade to the miller and manufacturer?

5. In what way does it serve the individual?

6. Is the trend of the market "up" or "down" for plant and animal products? How do they compare with those quoted in the daily paper?

THE BUREAU OF MARKETS (HOME PREPARATION)

Object.—To learn how our National Government brings farmer and merchant or producer and consumer together to the mutual advantage of each.

PROCEDURE AND OBSERVATION.—1. Correspond with the Bureau of Markets in the Department of Agriculture, asking for information relative to the purpose and working methods of the Bureau.

2. Consult library references, books, and magazines, for information concerning the Bureau.

3. Report: (*a*) The purpose of the Bureau.

(*b*) How it accomplishes its purpose.

(*c*) Is the bureau concerned only with the sale of plant products?

(*d*) The advantages of such a bureau to the farmer and gardener.

(*e*) The advantages to the individual buyer and consumer.

(*f*) Does the Bureau promote national welfare?

WATER AND SOIL

Object.—To make a study of the relation of water to soils.

PROCEDURE.—1. Turn to Chapter XIII. Review and recall the work done in the following experimental studies.

(*a*) How water rises in soils.
(*b*) Soils and soluble salts.
(*c*) The work of running water.
(*d*) A study of soils, rock, and erosion (a field trip). If the field trip as outlined in Chapter XIII was not taken at that time in the course, individuals should arrange to do so at this time.

PLANT FOODS (DEMONSTRATION FOR PUPILS)

Object.—To become acquainted with the essential plant foods and their sources.

MATERIALS.—Two one-gallon flower pots. Clean sand. One-ounce samples of *complete fertilizer* may be obtained from companies selling com-

FIG. 302.—Growth of oats with various fertilizers. *O*, Without addition to the soil; *KP*, available potash (potassium compound) and available phosphoric acid fertilizer have been added; *KPN*, available potash, available phosphoric acid, and nitrates have been added. (*From Palladin's Plant Physiology by Livingston.*)

mercial fertilizer, or from seed companies. Selected seeds of Indian corn, of beans, or of wheat.

PROCEDURE.—1. Fill the two one-gallon flower pots with clean sand that has been washed free from all organic material.

Label the pots #1 and #2.

Pour the top half of the sand in #1 onto a newspaper and sprinkle over it ⅕ to ¼ of an ounce of corn fertilizer as sent out by fertilizer companies. Thoroughly mix the fertilizer into every part of the sand and replace in

the jar. No foods are added to #2. Add just enough water to moisten the sand in each pot.

2. Plant 4 selected kernels of corn (or 4 beans or 36 grains of wheat) in each pot. Place in a warm window and keep each pot well moistened. Observe the growth of the corn in each pot each week for five weeks (Fig. 302).

3. Consult the text in this chapter relative to essential plant foods.

4. What is the composition of the fertilizer that was mixed with the sand in pot #1? Dealers in fertilizers give analyses of all samples that they sell. Such an analysis usually accompanies the package containing the fertilizing materials. Copy this analysis into your note book. Complete fertilizer must contain certain *available amounts*, called units, of nitrogen compounds (ammonia or nitrate), soluble (available) phosphoric acid, and water soluble potash. Insoluble fertilizers are worthless as plant foods. Why? A common type of fertilizer on the market is one having 2% ammonia, 8% of available phosphoric acid, and 2% of water soluble potash. Such a fertilizer is spoken of as two-eight two. Why? What is meant by a 3:10:5 fertilizer?

5. Conclusion. Are certain foods essential to plant growth? Name them. What results when soils are short of the essential foods? Is the welfare of a nation dependent upon its amount of fertilizing materials? Is there a way of conserving these materials? Explain. Consult text.

NITROGEN-FIXING BACTERIA

Object.—To make a study of a class of plants known as legumes which have formed a partnership with a class of bacteria in order to perform a very remarkable and wonderful work in the way of enriching soils with nitrogen compounds.

Apparatus.—Spade. Buckets or pans.

Procedure and Observation.—1. Read in the text concerning "Soils and Nitrifying Bacteria" and "Legumes and Nitrogen-fixing Bacteria." See Fig. 303.

Group A; Students

2. Locate a clover plant that grows in some waste place and carefully remove roots with dirt to a bucket or pan of water. When the dirt has become well soaked, move the roots up and down in the water to wash away the dirt. Renew the water and continue to wash the dirt away until the roots are clean. If the work has been carefully done many nodules attached to the roots will be observed.

3. Wrap a damp cloth or paper about the roots and remove to the class room. Mount the plant in a hole in a pasteboard cover—roots below and stems above—and place it over a jar of water so that two-thirds of the roots are in water and one-third above water. Place on view in class room or laboratory.

Group B; Students

4. Same as (2) except to secure a soy bean.

Group C; Students

5. Same as (2) except to secure an alfalfa plant.

Group D; Students

6. Same as (2) except to secure a pea plant.

7. Why are the above plants used by agriculturists to enrich soils? What plant food is added?

8. What is *rotation of crops?* What part do legumes play in crop rotation? Is crop rotation a good practice? Explain.

THE BALANCED AQUARIUM (DEMONSTRATION FOR INDIVIDUAL OR GROUP)

Object.—To make a study of a balanced aquarium in order to observe the interrelationship that exists between plant and animal life.

APPARATUS.—A two or three gallon glass jar.

MATERIALS.—Sand. Pebbles. Shells. Green water plants, rooted and floating. Snails. Tadpole. A small gold fish. Small water insects such as water fleas.

PROCEDURE.—Place two or three inches of sand in bottom of jar. Spread the roots of water plants on the surface of the sand and anchor them with pebbles. Fill the jar four-fifths or more with water. Add the floating water plants and the water containing water insects. Allow the aquarium thus prepared to stand in a place exposed to the light for several days.

Add several snails, a tadpole, and a gold fish. Secure the top with a fine screen. Observe from time to time for the remainder of the course and discover whatever relationship the activities of the living forms point out.

2. In such an aquarium it is not necessary to change the water. Explain in full.

2. What is meant by "balance of life?" Set forth the relationship that determines the balance of life for the animal forms that exist in the aquarium.

3. Does a balance of life exist among birds and their food supplies? Explain in one or more instances.

4. Is there a balance of life in existence for the total animal life of the world in its relationship to the total plant world?

5. What constitutes a balance of life for such noxious weeds as the thistle or burdock?

6. What constitutes the balance of life for any plant or animal?

Plants and Their Environment.—From early life, observation and experience are continually informing us concerning the

conditions affecting the growth of plants. From early childhood we know that plants require water. Later we learn that soil conditions are in some way concerned with the success of the plant. Then, too, we recognize that the sunlight and heat of spring and summer play a most important part in determining plant activities. The oak tree becomes a great and giant-like tree when growing in the open where the soil and the air and the sunlight are in abundance. But when growing from a crevice in a rock the oak remains a shrub, or when crowded by forest trees it sends up to the light a tall column-like trunk with a crown of leaves at the top. Instances like these and many others demonstrate to us in a most forcible manner the relation of the plant to the many conditions that surround it on every hand. In this connection we say the plant is related to its *environment.*

The various conditions and influences that make up the environment are referred to as *the factors of the environment,* which are food materials, water, air, heat (temperature), light, gravity, other plants, and animals. When the factors are favorable to the best growth of the plant, we recognize the plant as existing in a *favorable environment.* However, when one or more factors are out of proportion—too much or too little water, or insufficient food materials—the plant exists in an *unfavorable environment.* In short, *environment is the sum total of all the conditions and all the forces that influence the growth and development of living forms.*

Plant Modification and Environment.—In the preceding paragraph three oaks are considered as existing in three greatly different environments. The oak that grows in the open becomes great and giant-like for the reason that all the factors are in the right proportion for the best development in oak trees. The tree that grows in the rocky crag finds a greatly reduced store of soil foods and water supply, and so develops a plant body that is in every way greatly reduced. But in the forest, where all the trees are struggling for air and sunlight, the oak takes on a very different form and enters into the race in order to receive its share. Consequently, it produces a tall, slim, and columnar trunk in place of the massive trunk and the

robust branches of the oak that grows in the open. In each of the three instances the oak responded to the conditions existing in its environment and made such readjustments in form as were necessary for the greatest success.

From what has been said, it must not be thought that plants can make any degree of readjustment. Water plants, such as water lilies, cannot live in deserts or even in semi-arid places in which the cactus and sage bush succeed very well. Down through the ages the water lily has inherited structures and tendencies that fit it for its particular kind of environment in which water is an important factor.

During the centuries past the cactus family has fitted itself to live in the desert. It has withdrawn its leaves and branches to prevent excessive losses of water. It has covered its surface with a green structure that serves both as a protective covering and as a leaf. It protects its surface from browsing animals with numerous spines. It has a special provision for storing up water which serves it in time of drought. In short, the cactus has made many adaptations—deep-seated changes in structure and form —that fit it to live successfully in the waste lands of the desert. The water lily has made readjustments that fit it to the factors of environment as they exist in swamps and lakes, while the cactus has made those that fit it to live in the arid places.

Hence each plant requires a habitat in which the combination of the factors of environment is favorable to its growth and development. When the combination of environmental factors is not too greatly changed, the plant may make such adjustments as to be able to live quite successfully. Where the combination of environmental factors is such that the plant cannot make the necessary adjustments of form and structure, it weakens and dies.

Cultivated Plants and Environment.—In agricultural pursuits the agriculturist endeavors to bring about a combination of factors that will establish an environment suitable to the growth and development of his crops. He ploughs deeper for corn than he does for wheat or oats, because the roots of the corn need a deeper soil bed than does wheat. He tills the soil for the purpose of keeping out weeds and conserving the moisture in

the soil. If the weeds were allowed to grow, they would shade the plant and rob the essential foods and great amounts of water from the soil. Thus the presence of weeds would very quickly produce an environment in every way unfavorable to the crop plants. Cultivated plants are able to yield grains and fruits in abundance when their conditions of growth and development are not retarded by any unfavorable influences. Hence, when cultivated crops must enter into a contest with weeds for air, water, sunlight, and soil foods, there is bound to be a shortage in the harvest yield.

Everywhere the presence of insects and animals plays a greater or smaller part in determining the favorableness of the environment for a given plant. The work of leaf-cutting insects, such as the potato bug, robs the plant of its leaves and food-making apparatus. Plant lice (aphides) and scale insects withdraw the sap from the tender and growing portions of a plant and thus often ruin entire crops. Grasshoppers and the larvae of butterflies and moths eat as much as and often more than do the farm animals.

The noxious weeds, such as the ragweed, burdock, thistle, pigweed, etc., defend themselves with offensive odors, prickles, unpalatableness, and other disagreeable characteristics which lessen the danger of being eaten by insects and animals. The domesticated plants of orchard, farm, and garden have so long depended upon man for protection from unfavorable agents and forces that we find them today quite unprovided with any protective means. Since their tender tissues are usually well filled with rich foods which are very palatable and highly nutritious, cultivated plants fall a prey to every sort and kind of organism. Consequently a farmer or gardener who wishes to succeed must know how to control weeds, insects, fungi, scale, and many other similar pests that are ever waiting to invade the environment of his growing and developing crops.

Climatic Conditions Determine Environment.—Some of the factors that make up the environment of the plant are beyond the control of the farmer or gardener. The climatic conditions —hours of sunlight, temperature and temperature changes, abundance or lack of rainfall and wind—are beyond regulation.

It is excessive climatic conditions one way or another that give rise to such expressions as *cold season*, *wet season*, *dry season*, etc., which often exist to such an unfavorable degree as to lower the crop yield and in some areas completely to ruin the developing and growing plants. It was stated in Chapter X that the average climatic conditions for any particular region of our country are fairly constant and reoccur annually within limits that are fairly constant. Hence we find that the climatic conditions of the Gulf states are suited to the growing of cotton and sugar cane; of the states of Iowa, Illinois, Indiana, and Ohio, to the raising of corn and small grains; and of the Dakotas and Minnesota, to the production of wheat and grains. Consequently the success of crops in any region is largely dependent upon the agriculturist who selects plants best suited to the existing climatic conditions of the region in which his farm is located.

Kinds of Soil.—Fortunately the conditions of soil in the various regions mentioned above correspond favorably to the existing climate and make possible the greatest yield. The deep black loam of the Gulf states is as essential as the semi-tropical climate to the successful growth and development of the sugar cane and cotton. The clay loams of Iowa, Illinois, Indiana, and Ohio promote the abundant harvests of corn and small grains; while the glaciated soils of the Dakotas and Minnesota are in every way ideal for the production of wheat and other hardy grains.

In connection with the three regions mentioned above we have three interesting instances that set forth the different ways in which soils are formed. In the far past the Gulf of Mexico extended as far north as the mouth of the Ohio River. Year after year throughout the countless centuries the great river system of the Mississippi and lesser streams has been at work transporting materials from the highlands and building up the present great flood plain. Year after year vast loads of plant fragments, stems, bark, leaves, flowers, pollen, spores, fruits, roots, and even entire plants have been carried by the flood waters and spread over the lowland plains. Consequently the decaying vegetation has formed a deep layer of black organic soil rich in every kind of plant food. Consequently

in Mississippi and Alabama sharp contrasts exist between two regions—the sandy pine belt and the rich fine-soiled "black belt" where cotton grows. In the one region the farmers are poor and can scarcely make a living, while in the other are found the most prosperous people of the South.

When visiting the dumping ground of a stone quarry, one sees rock in all stages of disintegration and disorganization. The breaking down of the rock results in the formation of *clayey soils*, which are often very rich in essential plant foods. When the clayey soils are well mixed with the black organic soils from decaying plant and animal products, the resulting soil mixture, loam, is exceedingly favorable to the growth and development of corn, grain, fruits, vegetables, and abundant fodder crops. Such clayey soils overlaid with black soils, or mixtures of clayey soils and black organic soils, are found in the corn and grain belt extending across Iowa, Illinois, Indiana, and Ohio.

The history of the North American Continent indicates that great glaciers moved southward over the northern portion. These enormous masses of ice crushed and pulverized the rock materials to all degrees of fineness. The fine pulverized materials give rise to glaciated soils of wonderful texture, abundantly provided with plant foods. Minnesota and the Dakotas are well provided with glaciated soils which have proved to be well suited to the raising of all kinds of hardy grains and wheat.

Gravelly soils are the result when running water carries away the finer materials and leaves the coarser. Gravelly soils are hard to plow and to cultivate, dry out easily, and contain little plant food. *Sandy soil* consists largely of quartz particles. Sandy soil is easy to plow and to cultivate but, like gravelly soil, contains little plant food and dries out readily. *Clayey soils* are quite the opposite to gravelly and sandy soils. They contain quite a quantity of plant food. They are compact, and harden when they dry out. Many and most plants are unable to send their roots any distance in clayey soils. *Loamy soils* are various mixtures of sandy and clayey soils. When decayed vegetable matter, *humus*, is mixed with the loamy soils,

the farmer is rewarded with good crop yields. Peat and peaty soils were originally pure humus. Thus while clayey, sandy, and peaty soils are quite useless when pure, mixtures of these three soils are ideal for the best plant growth.

The Plant and the Soil.—We have learned that plants are able to build up starch from water and carbon dioxide. With the exception of those that live in water, plants receive their carbon dioxide from the air and their supplies of water from the ground. In this connection one may be led to believe that all plants should succeed equally well wherever they could secure water, carbon dioxide, sunlight, and heat. But this is not all, for, in order to grow, plants require compounds of nitrogen, compounds of phosphorus, compounds of potassium (potash), and slight quantities of the compounds of iron and silicon and other elements. All of these elements play some important part in the plant structure. Since none of these compounds exists in the air, the plant must find them in the soils.

Since the plant obtains all of its soil materials by means of root hairs that gather up the soil water by osmosis, it is evident that foods entering the root of a plant must be in solution. Thus the plant can never receive any phosphorus, potassium, or iron that is locked up in insoluble compounds. Much potassium is found in various kinds of soils and clays, but it is so combined in insoluble substances that it is unavailable for plants. Hence the growth and development of a plant are wholly dependent upon the store of soluble food substances in the soil in which it spreads its root system.

Soil and Nitrifying Bacteria.—Free nitrogen is everywhere in the air, but organized plant life cannot use it in the free state. In order to serve the plant, nitrogen must be a part of a compound such as a nitrate. But the formation of a nitrate is a very roundabout process which none of the green plants is able to accomplish. The question arises: "What does nature do to bring about the supplies of nitrates which are so necessary to the life and growth of plants?"

Existing in the soil are countless numbers of vast hordes of microscopic bacteria—one-celled plants—that are capable of

bringing into existence the required compounds of nitrogen. When leaves, straw, and similar plant remains fall to earth, they must go through various stages of decay before they become the desired humus which is so useful to the growing plant. The processes of decay are brought about by a class of bacteria that actually feed upon the complex structures of the dead leaves, straw, and other organic remains. As a result the digestive processes of the bacteria break up the leaf and straw materials into new and simpler substances. Some of the new substances they use as foods for their own bodies, and the others they throw off as waste products. One of the waste products that this class of bacteria throws off constantly into the surrounding soil is ammonia—a compound of nitrogen and hydrogen.

A second class of bacteria feeds on the ammonia and cast-off nitrites—compounds containing one particle of nitrogen and two particles of oxygen. A third class feeds on the nitrites and cast-off nitrates—compounds containing one particle of nitrogen and three particles of oxygen. These three classes of bacteria are known as the *nitrifying bacteria*. Without their presence the remains of every kind of plant and animal would be unavailable and wholly useless in the way of foods to growing vegetation.

Legumes and Nitrogen-fixing Bacteria.—There are still different bacteria which at times enter the roots of a certain class (legumes) of plants—clover, alfalfa, peas, soy beans, and other legumes. The bacteria invade the cells of the roots and produce a sort of an infection. The infected area enlarges and forms what is called a *nodule* or *tubercle* (Fig. 303). While living in the nodule, the bacteria are parasites and take food materials from the root on which the nodule grows. However, this class of bacteria requires free nitrogen, which it takes from the air that is found between the particles of soil. During the processes of digestion and assimilation that take place within the bodies of the bacteria, the nitrogen is combined with oxygen, and nitrates are thrown off as wastes. Thus everywhere about the root of a legume which has nodules there is a supply of valuable nitrates being thrown out into the soil. The legume absorbs and uses as much of the nitrates as it requires.

Where conditions are favorable, it is found that the bacteria throw off more nitrates than the plant is able to use. Consequently in the soil in which leguminous plants abound nitrates accumulate, and the soil is enriched. Since this class of bacteria makes use of free nitrogen and throws it off in nitrate compounds, they are known as *nitrogen-fixing bacteria*. Nitrogen-fixing

FIG. 303.—Roots of soy bean, showing nodules in which are located the nitrogen-fixing bacteria. (*After Piper: Leguminous Crops for Green Manuring. Farmer's Bulletin* 278, 1907, p. 20.)

bacteria and leguminous plants are of mutual advantage to each other—the legumes provide food and protecting nodules for the bacteria, while the bacteria fix the nitrogen into available nitrates for the legumes. *When two organisms form an association which is vital or helpful to each the intimate relationship is called* ***symbiosis*** *(**living together**)*

Crop Removals Exhaust the Soil.—When ripe fruit or vegetables are hauled away from the farm, or when a load of wheat or corn is carted away from the fields, the soil of the farm is being more and more exhausted. The fact is, however, that every crop that grows in the fields uses up the soil just as human beings use up food. Consequently each crop that is harvested and removed from the farm removes just so much of the valuable plant foods as the harvested crop gathered from the soil. Unless something is done to restore the removed substance, the farm becomes gradually exhausted and finally "worn out."

When plants grow wild in nature, the soil is kept rich, because each year's growth remains where it is grown. The vegetation decays and is again added to the soil. In the forest the leaves fall each year to form a leaf-bed that slowly rots and thus continually replenishes and enriches the soil with new humus and plant foods. The same process takes place on the prairies, where grasses and shrubs grow in the place of trees. Since the trees and grasses draw part of their nourishment from the air, the amount of humus that is returned to the soil is increased instead of being diminished. Consequently humus and plant foods accumulate in forest and prairie lands. In order that the soil be maintained, nature's method demands that as much humus and plant food be returned to the soil as was hauled away in the form of grains, fodders, fruits, and vegetables.

In 1915–16, Pennsylvania farmers produced on the average about 19 bushels of wheat to the acre, while in the State of Washington the average yield was close to 30 bushels per acre. South Carolina averaged about 20 bushels of oats to the acre, while Montana produced an average of nearly 53 bushels. The best average yields per acre for cotton, potatoes, wheat, oats, barley, rice, and hay all occur on the new lands west of the Mississippi River. Such conditions exist for the reason that new and uncultivated lands have not been exhausted of their humus and essential plant foods by removal of harvested crops.

Saving the Soil; Crop Rotation.—From what has been said it is quite clear that grain crops exhaust the soil of essential plant foods. Consequently, when grains are raised in the same

fields year after year, a farmer finds that the crop yield becomes continually less. To prevent the decrease in yield a thrifty farmer does one or both of two things: (1) by means of fertilizers he replaces the removed essential plant foods, or (2) he plants a crop of one of the legumes in order that the nitrogen-fixing bacteria may restore the necessary nitrates. Often the farmer plows the legume under as green manure, and thus adds to the soil not only much nitrogen but quantities of other valuable plant food and humus which make the soil lighter.

For the reasons given, clover, which is one of the leguminous plants, may be planted after the wheat is harvested. There is time enough in the fall for the clover to get a good growth before the frosts come. By early summer of the next year it yields a crop of hay. During the summer a second crop develops, from which seed may be harvested or upon which cattle may be pastured. A season of clover produces profit from the clover itself and in addition makes the soil ready for another harvest of wheat or some other crop that needs much nitrogen in the form of nitrates. Such *a change from a crop which takes materials from the soil to one that renews the soil is called crop rotation.*

In order to have an annual harvest of corn or wheat, a thrifty farmer divides his farm into a number of fields, and every year or two changes the crop which he raises in any one field. In some fields grains are grown, while in others clovers and grasses are grown for hay and pasturage. During the period of pasturage the "resting" soil is recovering its nitrogen compounds and other essential plant foods. In this way the farmer brings nature to his aid in the way of fertilizing his soils. Furthermore the thrifty farmer is sure to see that all barnyard soils and accumulations that result from feeding cattle and other livestock are annually returned to the soil of his farm. Barnyard accumulations are the most valuable single fertilizer that is obtainable. The accumulations contain much nitrogen and enough phosphorus and potassium compounds for most soils. Such manures contain great quantities of materials that serve as humus which improves the texture of the soil to which it is added.

There are several other advantages which result from crop rotation. A change in crops helps to kill weeds and destroy insect pests. Crops which have short roots that feed on the surface may be followed by crops that send their roots deep into the soil, and thus, under proper control, better crop yields are the result.

Machinery and Improved Methods.—In the middle of the last century, when all the work was done by hand labor, a farmer obtained, on the average, 2 bushels of corn as the result of a day's labor of 10 hours. A half century later the gang plow, disk harrow, corn planter, and corn binder came into use, and the average return for a work day of 10 hours rose to 14.5 bushels. In 1830 it took 6 days' work at 10 hours per day to produce 20 bushels of wheat on an acre of ground, while now with improved machinery the same results may be attained in 3 hours and 20 minutes. Eighty years ago the labor of a man for one day produced 45 pounds of cotton in the seed, whereas he now receives 127 pounds. Similarly in the production of other grains and agricultural products, the invention of farm machinery and improved farming methods have given the farmer a reward many times that which he received when hand labor was forced to prepare the soil and harvest the crop.

Coupled with the improved methods of farming are the improved methods of transportation resulting from improved roads, using motor trucks in place of horse-drawn vehicles, and more extensive steam and electric railways provided with cars for transporting to market every kind of farm produce. Furthermore, farm papers, agricultural journals, national and state farm bulletins, and other publications broadcast instantly any and all improvements in the various branches and kinds of agricultural pursuits.

Thus the farming populations are brought into commercial and intellectual relationship with all civilized mankind. The farmer no longer lives and works merely for himself and his family. He produces for the world, and his prosperity depends upon the prices that the world can pay for his products and the possibility of shipping what he raises to those who need it. This means that the farmer is concerned with many things

which are outside his rural neighborhood. He must understand how freight rates are established, how prices are set, how laws are passed, how taxes are levied and appropriated, the purpose of agricultural colleges, experiment stations, and bureaus. In short the farmer must realize that the question of agriculture is a part of every national and international situation.

Feeding the City.—At the beginning of this chapter it was stated that 39% of the population of our country is engaged in agricultural persuits. This means that 39 people out of every 100 are able to produce enough food and raw materials to feed and clothe 100 people, or sufficient above their own uses to feed and provide clothing materials for 61 individuals living in towns and cities. Hence to feed daily the great concentrated populations found in New York City or Chicago involves such vast stores and stocks of foods of every kind as to tax the producing capacity of several states.

During the year 1914 when the prices were normal, Chicago alone used $25,000,000 worth of milk and $29,000,000 worth of butter. In order to supply this vast volume of dairy products, it required the combined producing capacities of Wisconsin, Michigan, Iowa, Indiana, and even Minnesota. To think of all the fields and pastures that produced the grains and grasses that fed the cows that provided the milk and butter, rivals any fairy tale in story and romance. The largest item on Chicago's market bill for that year was $87,000,000 for meats, which came from the ranches and farms of the western plains extending from Montana to Texas. Similar figures might be given for wheat, corn, eggs, potatoes, vegetables, fruits, and other foods. And when all is taken together, one begins to understand why the railroads are constantly bringing into any great city from distant parts the many food stuffs that supply its table needs.

City Markets.—In small towns the markets are supplied by the farmers who drive in with small loads of food that have been produced in neighboring regions. However, in small towns some foods must come from greater distances. Meat is commonly imported from packing houses in Chicago, or Kansas City, or Omaha. The neighboring farms seldom produce all that even a small town requires. When the town

grows larger, the distance from which its food supply is brought must increase in proportion. In this connection the railroads serve the town or city as its great arterial system that reaches out, collects, and brings in its supplies of food materials.

As the city grows larger, its buying and selling methods become more and more organized. Certain traders and merchants buy and sell only one sort or kind of produce. For instance many traders handle only poultry; others deal in eggs, or butter, or apples and fruits, or potatoes and vegetables. Each group is a "specialist" in the buying and selecting of a particular kind of produce.

Larger groups of men become organized for the purpose of receiving live stock. To this end they build and equip vast stock yards which receive, care for, and classify all the live stock that arrives by the train load at all hours of the day and night. Early the following morning buyers for packing houses and other concerns go from yard to yard and bid on the animals, which of course are sold on the highest bid. From day to day the bids vary from one level to another. When the supply of live stock is large and continuous, a bidder may buy on a lower bid than when the number received is small and the bidding by other buyers forces up the selling price. However, a great many other conditions enter into the general market conditions and play a part in determining the amount a buyer is willing or able to bid.

Similarly organized are the cotton markets of New Orleans and New York, the sugar markets, the grain markets, and those of every other kind. In these instances the buying and selling is conducted by organized groups of men that make up what is known as a board of trade.

The Farm and the Market.—When one turns his attention to the markets of the world, he realizes the great dependence of every kind of activity upon the success of the farmer. The cotton mills, the woolen mills, the shoe factories, and their allied industries depend upon the success of the cotton grower or the producer of sheep and cattle. The workers in the mills depend upon the producers of wheat, meats, dairy products, fruits, vegetables, and food stuffs of every kind. Think

as we will, our minds carry us back continually to the makers of the original food substances—to the green plants of all sorts. It is all the work of green leaves on the crop plants when properly supplied with soil foods, water, carbon dioxide, and sunlight. They bring into existence the great supplies of food—breads, meats, fruits, vegetables—and the great supplies of clothing and building materials—cotton, wool, silk, leather, lumber—that nourish, clothe, and house the great human body. It is all the result of green leaves in the service of man.

Projects

1. To learn to identify the various kinds of woods and the principal uses of each.

Suggestion.—Collect samples of uniform size. Have them sawed and planed so as to show cross and lengthwise sections. Label each specimen.

2. To learn the sources of the various mineral fertilizers and to compare the supply with the needs and demands for them.

Suggestion.—Locate on a wall chart of the world the nitrate beds, the localities in which rock phosphates are mined, potash mines, etc., and display the chart. Collect and display samples of raw and mixed fertilizer.

3. To learn how and when to spray fruit and shade trees in order to protect them from the ravages of insect enemies.

4. To learn to identify the various noxious weeds and how to control and eliminate them from garden and field.

Suggestion.—Display specimens of noxious weeds.

5. To make a study of noxious weeds for the purpose of learning the means employed by them for discouraging browsing animals and various kinds of insects that feed upon the green and tender portions of plants.

Suggestion.—Consult Harshberger's *Pastoral and Agricultural Botany.* Make a field trip and discover some of the methods by actual observation.

6. To make a list of the many kinds of foods found in the various markets of a city and to learn the source of each.

Report in the form of a table.

Article of food	Region
Potatoes	New Jersey; Montana
Bananas	Cuba; Central America
Pineapples	Porto Rico
Oranges	Florida; California
Tea	India; Japan

7. To learn how people of a city help to satisfy the wants and needs of those who live in the rural districts.

8. To show that it is just as important to save food as it is to produce food.

9. To show the relation of the railroads to the raising of wheat.

10. To show that the improvement in farm machinery is a cause of the great growth of American cities.

11. To learn the conditions that determine the balance of human life as regards that portion living in the rural districts and that in the cities (producer and consumer).

12. To learn the conditions that determine the balance of life as regards the relationship of plant and animal life.

13. To point out the conditions that gave rise to food shortages in Europe during the World War.

14. To point out the conditions that gave rise to food shortages in Europe for the years following the World War.

15. To point out the conditions that give rise to food shortages in China.

16. To show that concentration of industry related to the preparation of food stuffs is often necessary.

Suggestion.—Select the meat packing industry; milling of wheat; and similar industries. Does the concentration of industry tend toward the elimination of waste through the manufacture of useful by-products?

UNIT II

THE SIMPLE ORGANISM

Life in Its Simplest Form; a Summary.—Many times in the course, study has been given and reference has been made to conditions that are favorable and unfavorable to life. Much has been put forth concerning protoplasm as the only substance possessed of the characteristics of life. By means of the microscope we have observed those minute units of life—the cells—and their structures, consisting of cell wall, cytoplasm, and nucleus. We have, in a brief way, observed and studied the individual cells—paramecium, amoeba, and vorticella—that are capable of performing in a simple way all the functions of life. We have considered the nitrifying and nitrogen-fixing bacteria, and, although we have never seen them, we are able in a way to appreciate and actually to realize the importance of their presence in the soils of the earth.

In our work with the flowering plant, we became acquainted with root-hair cells, guard cells of the stoma, palisade cells, pollen and pollen cells, ovules, and fertilized egg-cells. In short, we found a plant to be composed of many kinds of cells. Each kind was organized into a tissue which was fitted (specialized) to the performance of one labor—a special labor. For example, root hairs were so specialized as to be able to gather the soil waters, while the cells in the palisade layers of the leaf were so specialized that they were able to arrest the sunlight by means of chlorophyll and thus to produce starch from carbon dioxide and water. From the very nature of the case it was clear to us that root-hair cells could not do the special labors assigned to the palisade cells of the leaf, and likewise that the palisade cells of the leaf could not perform the special labors of the root-hair cells. Yet the plant lived, because each group was at work performing its special labor, and the sum total of all the labors of the many groups of cells resulted in a successfully living plant.

In this connection it is well to observe that a root-hair cell, or any other cell that makes up the body of a plant, is quite unable to live alone. If any one cell of a plant becomes separated from the plant organism it dies, because it is unable to shift for itself for the reason that it is unable to perform the several functions of life. The paramecium is not so dependent, for it can go in search of food, which it is able to select, seize, digest, and assimilate. Thus we have two kinds of one-celled organisms—(1) those cells that live, more or less, quite independently of the services of others, and (2) those that have so specialized themselves that they are able to live only when associated with other specialized groups.

Since all living forms consist of single cells or groups of specialized cells the theme of this unit is cell life.

CHAPTER XXV

FUNCTIONS OF LIFE PERFORMED BY THE SINGLE CELL

Object.—To make a study of one-celled organisms and their habits of living, in order to understand the fundamental processes of life as it occurs in these simple organisms.

The Mystery of Cell Life.—Before the discoveries and studies of Louis Pasteur, the world remained in ignorance concerning the presence of microscopic forms of life. When grape juices and ciders fermented, when meats decayed, or when fruits developed molds, the people were unable to account for the cause of what they saw. The student and scientist of the time ascribed the cause to *spontaneous generation*. That is, they had the notion that any inorganic or decaying organic materials could give rise to living organisms without previously existing parents. In this connection Pasteur was finally able to bring forth convincing proof that spores and germs of every kind were constantly present in the air. Later studies confirmed his labors, and today, with the aid of improved microscopes, we are able to view and to point out the many kinds of minute one-celled organisms that cause fermentation, decay of meats and fruits, and disease in plant and animal structures.

Since these simple organisms have such an intimate bearing upon the lives of all of us, the theme of this chapter is concerned with the simplest forms of life, which for our convenience are grouped into two great classes: simplest plant forms and simplest animal forms. The simplest plant forms include three well known groups: (1) the *algae*, such as green pond scums; (2) the *bacteria*, such as the nitrogen-fixing bacteria and the bacillus of tuberculosis; (3) the *fungi*, of which yeast cells are representative. The simplest animal forms are known as *protozoa*, of which the amoeba, paramecium, and vorticella are examples.

THE ALGÆ

Object.—To make a study of that class of one-celled plants that contain chlorophyll within their structures, in order to become acquainted with their way of effecting a living and their economic importance.

APPARATUS.—Microscope. Glass slides. Cover glass. Beaker or glass. Needle.

MATERIALS.—Pond scum in gallon jar or aquarium. Bits of bark that look green and have been kept moist since they were gathered from the side of a tree trunk.

PROCEDURE AND OBSERVATION.—1. *Pleurococcus.*—(*a*) By means of a needle loosen a small bit of the green substance from one of the pieces of bark. Mount in a drop of water and cover and examine with low and high powers of microscope.

(*b*) If the mass of green was well removed and free from bark, it will be seen to be made up of little rounded green cells. Each cell has a cell wall, cytoplasm, and nucleus. This little organism is a plant and is called *pleurococcus* or *protococcus*.

(*c*) Observe the presence of chlorophyll. Of what use is it? Is the little plant independent? Explain. Why does it appear only in moist places? Why does it flourish in wet weather? Which side of a tree or rock wall is more favorable to its growth, the north or south side? On which side of buildings is "green slime" the more frequent? Why? What does it need besides light and moisture in order to make starch?

(*d*) Some of the pleurococci will be found to be elongated. Some may be dividing into two by *cell-division*. Sometimes there are two or more cells still clinging together and thus showing that they have just been formed by division. If time permits, make and examine other mounts of pleurococcus.

2. *Spirogyra.*—(*a*) By means of the needle remove one or more of the green thread-like structures from a mass of pond scum. Mount and examine with the microscope.

(*b*) Are you able to locate the spirally wound bands of chlorophyll within the elongated cells? Are the cells which compose the thread fastened end to end? This form of algae is called *spirogyra* (Latin: *spira*, a coil; *gyre*, a circular motion).

(*c*) Of what purpose is the chlorophyll? Does the spirogyra obtain its carbon dioxide from the air or from water? Do fish and other water animals give off carbon dioxide to the water ? Does the spirogyra give off oxygen? Do the fish feed on the water plants? Point out the various relationships existing between plant and animal life as it exists in pond or lake. Is there a balance of life in such instances? Point out one or more instances.

3. From your study of the pleurococcus and spirogyra, summarize the economic importance of the algæ.

BACTERIA AND FUNGI

Object.—To make a study of that class of simple plants that contain no chlorophyll within their structures, in order to become acquainted with their manner of securing a living and their economic importance.

APPARATUS.—Microscope. Cover glasses. Glass slides. Four wide mouth bottles. (Two bell jars and 2 plates and 1 flask per class.) Access to ice box.

MATERIALS.—Yeast cake. Sugar. Bread. Fruits with growing molds. Milk. Cotton.

PROCEDURE.—1. *Bacteria.*—(*a*) Recall the presence of the development and growth of bacteria in the early stages of the hay infusion (not the large one-celled animals such as the paramecium and vorticella). Recall the presence of nitrogen-fixing bacteria within the nodules of leguminous plants.

(*b*) Recall or review:

In Chapter XI: "Dust and micro-organisms in the air," "Air pollution," "Air, dust, and bacteria," and "Keeping the air in cities clean."

In Chapter XIV: "Water and microscopic forms of life," "Microbes and bacteria," "Purification of water and filtering processes," "Sewage treatment," and "Mosquitoes and disease."

2. *Molds.*—(*a*) (Instructor or student). Place a slice of bread upon a plate which is larger than the mouth of a bell jar, and expose the bread for 24 hours to the passing currents of air. Why?

Moisten the bread and cover with a bell jar. Place in the light. (*b*) Same as (*a*) excepting that the prepared specimen is kept in the dark.

(*c*) After two or three days observe daily. During regular laboratory periods examine the molds with a microscope. Is there evidence of chlorophyll? Do the molds grow equally well in the light and in the dark? Explain.

3. *Yeast.*—(*a*) (Instructor or student). Place yeast cake in wide mouth bottle. With a small quantity of water work the yeast cake into a paste. Fill bottle and stir contents thoroughly. Divide the quantity thus prepared among four wide mouth bottles labeled from 1 to 4.

(*b*) Add one tablespoonful of sugar to bottles #1, #2, #3. Place a wad of cotton in the mouth of each. Why?

(*c*) Set bottles #1 and #4 in a warm place. Set #2 in an ice box or other cold place. Pour contents of #3 into a flask, boil, and loosely plug the mouth of the flask with cotton. Why? Set the flask and prepared contents beside jars #1 and #4.

(*d*) (Pupils) After 24 hours examine with the microscope the contents of each of the four bottles.

(*e*) In which of the bottles did yeast cells develop? In which of the

bottles did yeast cells fail to develop? Name all the factors favorable to the development and growth of the yeast cell.

Name the factors unfavorable to the development and growth of the yeast cell.

Make a study of the yeast cell by looking for the cell wall, shape, buds for the production of new cells, absence or presence of chlorophyll.

Are yeast cells independent or dependent plants?

Whence came the yeast spores that developed into yeast cells?

What is meant by "*sterilizing with heat?*" By *pasteurization?*

CARRIERS OF BACTERIAL DISEASES

Object.—To investigate the various ways that result in the transmission of bacteria and spores that cause disease, and to find means for controlling them.

APPARATUS.—Microscope. Glass slide. Cover glass. Needle.

MATERIALS.—Fly. Flea. Roach. Other house-visiting insect pests that may serve as carriers of bacteria and spores.

PROCEDURE AND OBSERVATION.—1. Swat a fly. Using the needle remove such portions as legs, or head, or wings. Mount on a glass slide and cover with glass. Bring a slight pressure to bear upon the cover glass in order to flatten the mounted portions. View with low power of the microscope.

Are the body, head, and legs of a fly well adapted to the carrying of dirt and filth of every sort?

What diseases are frequently deposited on food materials and food containers by feeding and visiting flies?

2. Repeat (1) for flea, roach, and similar insect pests.

3. Assign as individual activities:

(*a*) Write to the American Medical Association, 535 N. Dearborn St., Chicago, for "The House Fly—Carrier of Disease." Read the pamphlet and report on diseases commonly spread by flies.

(*b*) Write to the International Harvester Company, Chicago, for literature relative to the house fly and for the loan of lantern slides "Fight the Fly." Arrange with your instructor to show the slides. Interpret each slide.

(*c*) Write to the Department of Agriculture requesting bulletins relative to the control of flies. Report methods of control.

(*d*) Same as (*c*) for fleas, roaches, and bed bugs. Report methods of control.

(*e*) Same as (*c*) for rats and mice. Report common diseases which they spread, and means of controlling them.

(*f*) Write to the United States Public Health Service, Washington, D. C., for The Supplement to the Public Health Reports for "Safe Milk." Report on "Bacteria in Milk," "Diseases which may be conveyed by Milk," and "Prevention of Milk-borne Diseases."

The Work of the Simplest Forms of Life.—Forces—heat, cold, erosion by wind and water, etc.—are constantly at work shattering, splintering, and pulverizing the rock masses that make up the crust layers of the earth's surface. Coupled with these forces in nature are the simplest forms of life—the algæ, the bacteria, and the fungi. Wherever there is water and carbon dioxide, there is carbonic acid which results from the union of water with carbon dioxide. Although it is very weak,

FIG. 304.—A solid-rock surface covered with the simplest forms of plant life—pleurococcus, lichens, mosses, and others. In the background are shown the encroaching higher forms—grasses, shrubs, and trees. Why do the lower forms precede the higher forms? (*From Hamaker's Principles of Biology.*)

carbonic acid exerts a slight dissolving action on the surface of rock particles. Wherever there is carbonic acid in the waters and layers of moisture, the various forms of algæ—pleurococcus, spirogyra, and others—establish themselves; by photosynthesis they build the dissolved substances into foods; they develop, grow, and reproduce in abundance. As the process continues, layers of cast-off plant materials accumulate. In the accumulated plant remains, processes of decomposition are brought

about by the action of the nitrifying bacteria. In this way, soil enriched with humus has little by little spread over all the earth. From the beginning of time the algæ and bacteria have been at work preparing the way for the highest forms of plant life—for all the life of the earth.

The Pleurococcus.—In moist climates and during moist seasons, most of us have seen green layers appear on shaded surfaces of stone walls, rock surfaces, wooden fences, and the bark of trees. Close examination shows that such green slimes are composed of countless numbers of microscopic one-celled plants. This little one-celled plant is called *pleurococcus*. Each consists simply of a cell wall, cytoplasm, nucleus, chlorophyll, and cell sap. No plant or animal form could be more simple in structure. While it appears to be associated in groups or masses, each of the little cells is quite independent of the other.

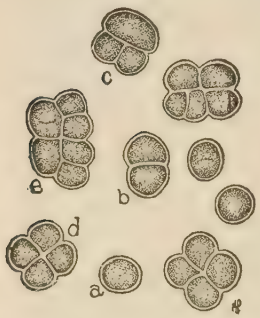


FIG. 305.—Individual plants of green slime, the *pleurococcus*, showing the tendency of the cells to remain attached after cell-divisions have taken place. (*From Gager's Fundamentals of Botany.*)

In the case of the pleurococcus there are no roots, no holdfasts, no stems, no leaves, and no flowers. Under such conditions each minute cell must carry on for itself the processes of absorption, photosynthesis, digestion, respiration, assimilation, excretion, and reproduction. Hence, while the pleurococcus appears exceedingly simple in structure, it is capable of performing all the life functions of higher plants. The pleurococcus is a green plant reduced to its lowest terms. While it is the simplest expression of plant life that exists, it is highly successful and occurs in every region of the earth.

The Spirogyra.—During the warm season of the year, green masses of pond scums are seen floating upon surfaces of ponds and sluggish streams. Upon close examination the pond scums are generally found to consist of masses of thread-like structures. When one of the threads of the pond scum is examined under the microscope, a beautiful spiral arrangement of chlorophyll bands (Fig. 306) is at once observed. From this

arrangement of the bands of chlorophyll in each of the elongated cells, the plant receives its name *spirogyra*.

Since each cell of the filament is provided with chlorophyll, it is able to live independently of other cells in the same filament. Each cell gathers by osmosis such quantities of food materials as it is able to find in the water, and by photosynthesis manufactures its own food. During seasons favorable to the manufacture of food the cells grow and divide. Since the cells always remain attached end to end, the growth and division of cells results in lengthening the filament.

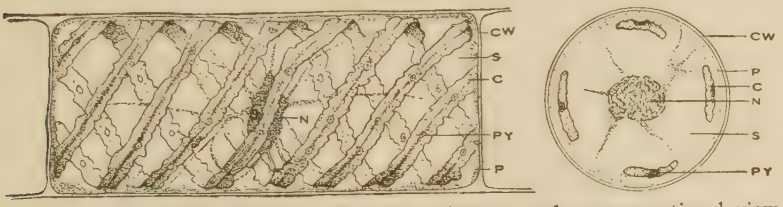


FIG. 306.—A side view of a cell of the spirogyra and a cross-sectional view through the nucleus. *C*, Bands of chloroplasts; *CW*, cell wall; *N*, nucleus; *P*, protoplasm; *S*, cell sap. (*From Atwood's Civic and Economic Biology.*)

The spirogyra is continually removing carbon dioxide and other dissolved substances and manufacturing them into starch and proteins and throwing off the excess supplies of oxygen. Thus spirogyra and other forms of water algæ not only aid in keeping the water supplied with oxygen, but serve as the primary food for the smallest water insects, the crustaceans, and even for the largest fishes. Aquatic animals depend upon the algæ in the same manner that land animals depend upon herbaceous plants. Without the algæ fish would soon die, because their supplies of food would be wanting.

Spirogyra: Reproduction by Conjugation.—When the plant filament of a spirogyra becomes broken into two or more parts, each part develops a separate plant. This process of increasing the plant numbers is known as *vegetative reproduction*. At times, a kind of reproduction which is different from any yet studied takes place. When the plant filaments lie near to each other, the cells of two plants may push out tubular extensions. The extensions meet and fuse into a tube-like passageway that leads from one cell to the other (as shown in Fig. 307*B*). The con-

tents of one cell pass through the tube and unite with that in the other cell. The new mass becomes much condensed and greatly thickened, and a heavy cell wall takes the place of the previously very thin one.

Since the newly formed cell with its heavy wall is the result of the union of two cells, it is called *zygospore* (which means a

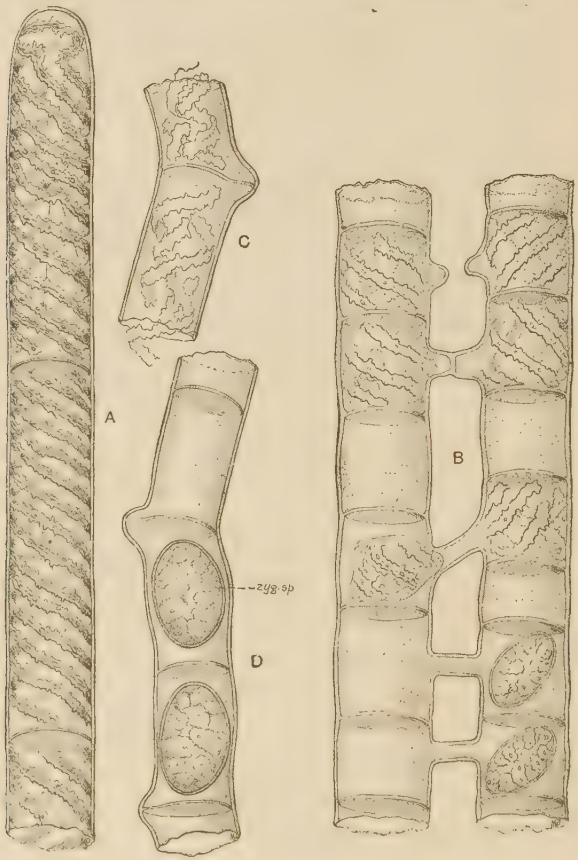


FIG. 307.—Spirogyra. *A*, Terminal portion of a filament showing two whole cells; *B*, stages of conjugation; *zyg. sp.*, Zygospores, four are shown in the illustration. (*From Gager's Fundamentals of Botany.*)

yoked spore). When two cells of the same kind unite to form a new cell, the process is called *conjugation*. *Conjugation* or *cell union* is quite the opposite of *cell-division*. In the one instance two cells are brought together for the formation of the

new cell, while in the other the cell divides (by fission) to produce two new cells. Reproduction by cell union or conjugation is known as *sexual*, while that of cell division is known as *asexual*.

The zygospore, being heavier than the water of the pond, sinks to the bottom and awaits a period favorable to its development into an active plant. Occasionally two adjoining cells of the same plant may unite (Fig. 307*C*) and form a *zygospore*. Often a cell that has not united with other cells will thicken its wall and take the form of a *spore*. Such spores are called *resting spores*.

The Purpose of Spores.—Since the algæ thrive best in shallow waters, the ponds in which they grow undergo extreme conditions of heat and cold. In the summer the ponds may become greatly warmed or dry up, while in the winter the ponds may freeze solidly from top to bottom. In either case the conditions for active life and growth are unfavorable. Hence one readily discovers the purpose of heavy-walled and dormant spores. When the waters of the pond have evaporated, the spores are incased in the dried earth and await the return of the rainy season. Likewise throughout the low temperature of winter the spores lie at the bottom of the frozen ponds. Thus by means of spores, the algæ succeed in existing throughout the varying seasons and in continuing their kind throughout the centuries.

The Bacteria and Fungi; Dependent Plants.—Those plants which have no chlorophyll are unable to manufacture their required food materials. Consequently plants having no chlorophyll must have their foods prepared for them. Such plants are, of course, dependent plants. Since there are two kinds of foods—dead organic substances and living organic substances—dependent plants are classified according to the kind of food they use. Those that feed on lifeless organic materials —mold on bread—are called *saprophytes*. Those that feed on the living tissues of plants and animals—typhoid bacteria in the blood—are known as *parasites*.

A numberless host of simple plants make up the great group of bacteria and fungi. Like those of the algæ their structures are extremely simple. Some are useful and essential to the pres-

ence of all life on the earth, while others are capable of giving rise to death-dealing diseases. In either case the economic results make it imperative that we have some knowledge concerning the working habits of this group of plants.

Classification of Bacteria.—Bacteria are classified according to their form or appearance. The round bacteria are known as *cocci*—ball shape. They occur singly or in groups. The long bacteria which have their ends rounded like spindles or shuttles are called *bacilli*—rod shaped. Those bacteria which appear like spirals are named *spirilla*. (See Fig. 119.)

Bacteria and Their Reproduction.—The usual method of reproduction in bacteria is by fission, in which a process of cell-division divides the cell into two new cells. The newly formed cells separate, grow, and repeat the process of fission. In some instances two and even three generations may be formed in an hour's time. That is, during the hour a bacterium divides into two new individuals, which then give rise to four, which in their turn form eight. If all the conditions of food, moisture, temperature, etc., remain wholly favorable, an individual bacterium, which gives rise to two generations per hour, would at the end of a day's time have an offspring numbering not far from 300,000,000,000.

Only under the most favorable conditions can such a rate of reproduction be carried on. However, the food in such instances is continually becoming less, and the excretion of wastes and poisons is becoming greater. The decrease in food and the increase in poisonous wastes soon develop a condition that is unfavorable to rapid growth, and in many instances to any form of activity whatsoever. In short, the number of bacteria is ever determined by the question of food supply. Between bacterial numbers and food quantities there is ever a balance—a *balance of life* in which the predominance of bacteria is prevented by a lack of food.

In a few kinds of bacteria there is found another kind of reproduction in which the interior of the bacterial cell becomes rounded and enclosed in a heavy wall. This heavy walled body is known as a *spore*, which is highly resistant to unfavorable conditions that may surround it. Like the zygospore

of the algæ, the bacterial spore tides the life of the particular kind of bacteria over unfavorable periods. In the spore state bacteria are exceedingly difficult to destroy, and it is, indeed, very fortunate for mankind that very few of the spore-forming bacteria produce diseases in the human family. A disease known as anthrax is the result of a spore-forming bacteria. Anthrax attacks cattle, sheep, rats, mice, and other animals, including man.

The Work of Bacteria and Fungi.—The living creature restores to nature what it has absorbed, and eventually its own body, by excretions during life and by its decomposition after death. So accustomed are we to observing the building up and the breaking down, the composition and decomposition of organic substances, that it seldom occurs to us what the result would be if either of these processes should cease to exist. It may be, perchance, that we have often desired that the conditions which bring about decay and decomposition should cease, for they seem to be opposed to our very existence. In such an event we fail to foresee a world full of accumulated organic remains. The land surface would be covered with the excretions and the remains of animals and plants of every kind. Likewise the oceans, the seas, and the lakes would become intolerable with huge quantities of the remains of every kind of water-living organisms. Eventually conditions would become such that life would be impossible, and forms of life of every kind would pass out of existence.

Happily and most fortunately, then, the bacteria which cause decay, the yeasts and other fungi, are continually at work breaking down the cast-off materials and the remains of plant and animal life. Fermentation, putrefaction, decomposition, and decay are the result of bacterial processes that restore to the atmosphere and to the soils of the earth the elements and substances which the plants and animals have borrowed and which nature so kindly loaned. Age after age the first great workers in the cycle of life are the bacteria of decay and their assistant workers, the fungi. Thus life could not continue without bacteria; while they do not create life, they supply it with the necessary material.

Activities Dependent upon the Aid of Bacteria and Fungi.—Already it has been pointed out how the farmer and agriculturist maintain the fertility of their soils by providing conditions favorable to nitrifying and nitrogen-fixing bacteria, and how the people who live in cities employ bacteria for the purification of sewages. Many other industrial uses are made of the labors performed by bacteria. In the dairy certain kinds of bacteria bring about the ripening of milk in butter and cheese making. It is the work of bacteria that produces the pleasant flavors in many kinds of cheese, and it is also bacterial work that produces the unpleasant flavors in unclean dairy products or in those that have been long stored. In the manufacture of wines, beers, fruit vinegars, saur-kraut, digestive ferments, in tanning, bread making, in curing tobacco, and in many other processes, certain bacteria, molds, and yeasts play a more or less important role that is vital to the success of the industrial activity.

Activities Opposed to the Work of Bacteria and Fungi; the Preservation of Foods.—Since bacteria, molds, and yeasts are everywhere present and ready to begin processes of decomposition in each and every kind of organic substance, man must protect his food materials from the ravages of these agents. Since bacteria and fungi are just as dependent upon conditions favorable to their development and growth as other organisms are, man seeks to control them by making one or more of the conditions unfavorable to their existence. In order to preserve his hay, grains, fruits, and similar materials, the farmer dries them and stores them in dry storage places, for in the absence of water the spores of bacteria and fungi remain dormant.

Perishable foods, such as butter, eggs, meats, fish, fruits of all kinds, and some vegetables, are kept in cold storage, where the temperature is kept at a degree unfavorable to growth and development of bacteria and fungi. Formerly in this country and still in other countries where cold storage methods are not the custom, meats of all kinds are smoked with wood smoke. In this manner creosote is carried to the surface of meat, which it penetrates and preserves by preventing the growth of destructive organisms. Large quantities of fish are still preserved in this manner.

The housewife by means of heat properly applied kills all the bacteria and other organisms of decay that exist in and about the foods which she wishes to preserve. If such sterilized food is sealed in vessels that have been similarly sterilized, it will not decay. In this manner great quantities of fruits, confections, vegetables, and meats are stored away in the home and in warehouses of large canning factories. The sterilization and canning of foods is one of the great industrial pursuits of our country. The surplus foods of one season or region are thus saved for use.

In the art of canning food stuffs it is difficult to sterilize thoroughly the food, containers, and the sealing appliances so that no organism whatsoever will develop. On account of this there is a temptation to add certain chemicals that prevent the development of bacteria. These chemical preventives are poisonous, and their presence is generally indicative of unclean methods during the canning processes. When such chemically treated foods are eaten, injurious effects to the health are not immediately noticeable, and for this reason many people see no danger in such practices. With each passing year the quantity and kinds of canned foods coming to our table are becoming more numerous. Consequently, if each and every canned food article contains small quantities of poisonous preservatives, the total amount introduced into one's body day after day is sufficient to undermine the health, to produce serious disturbances in the human machine, to shorten the period of usefulness, and to increase the number of national ills.

Protozoa; One-celled Animal Life.—Earlier in the course (Chapter XIV), some of the one-celled animals, the amœba, paramecium, and vorticella, were observed at work, and some of their habits of life were pointed out. These one-celled animals are called *protozoa* and are of much interest on account of their simplicity of structure and behavior.

In the simple body of the amœba we find no legs or fins or wings provided for locomotion, yet it is capable of moving from place to place. Without lungs or gills it is able to respire, without stomach or intestines it is able to digest its food, without heart or blood vessels it circulates the fluids within its

structure, and without sense organs or a nervous system it is sensitive and responds to stimulation. The bit of protoplasm within its cell wall performs all the functions of life in a way that is sufficient to enable the amœba to live and to reproduce its kind by fission, or conjugation, or spores.

Although the protozoa are small in size, they exist in such great numbers in all bodies of water that they play an important part in the life of the world. They devour bacteria and other simple plants, they prey upon other protozoa, and like the bacteria of decay they are continually at work ridding the earth of dead organisms. In their turn the protozoa serve as food for countless numbers of small animals that devour them unceasingly. Together with the bacteria of decay the protozoa free the waters of the world of dead organic materials by converting them into wholesome foods for the higher forms.

Bacterial and Protozoan Diseases.—While many bacteria and protozoa find their food materials in lifeless organic materials, many bacteria and protozoa exist wholly or in part on materials which they rob from the tissues of living organisms. In this connection it must never be forgotten that wherever bacteria and protozoa are digesting and assimilating foods, they are at the same time throwing off waste materials. Consequently, when these minute organisms invade the tissues of an animal they do two things: (1) they use up the vital portions of the tissue in which they live, and (2) they return to the tissues and circulatory system their excretions, which are more or less poisonous.

When excretions of bacteria or protozoa cause disease effects in the animal in which they live, the excretions are specially named *toxins*. Since each disease-producing bacteria produces a different kind of excretion from every other kind of bacteria, each produces its special kind of toxin. When sufficient toxin has collected in an animal body, it produces effects that are recognized as *disease*. Different toxins give rise to different diseases. Thus when the doctor is called to diagnose a disease, he studies the effects that are being produced by the toxins that the bacteria are throwing off within the patient's body. From the particular effects he recognizes the disease as measles,

scarlet fever, mumps, diphtheria, smallpox, or whatever he finds it to be.

Some Microbial Diseases.—The more common of the bacterial diseases are tuberculosis, typhoid fever, pneumonia, whooping cough, diphtheria, dysentery, and tetanus (lockjaw). The microbes that cause the following diseases are as yet unclassified: scarlet fever, measles, German measles, smallpox, chickenpox, mumps, and influenza. Well-known diseases caused by protozoa are sleeping sickness and malaria. A small group of molds cause skin diseases, the best known of which are barber's itch and ringworm.

Immunity and Susceptibility.—When disease-producing bacteria enter the body and start to throw off toxins, the tissues of the body make a counter attack and endeavor to create substances that oppose or neutralize the poisonous effects of the toxins. To this end the tissues manufacture an *antitoxin* which, when produced in sufficient quantities, counteracts the influence of the poisonous toxins. In some cases when one has had a disease and has produced sufficient antitoxin to overcome the attack, he is usually not again susceptible to this particular disease. Smallpox is one of the diseases which one rarely, if ever, has the second time. During the first attack the person who survives has acquired *immunity*. Such a person is said to be *immune* to future attacks. In short, immunity is resistance to disease.

There are other diseases against which most people may acquire immunity by once surviving an attack. Notable among these are diphtheria, measles, scarlet fever, and the mumps. The period of immunity is usually for the remaining portion of life, though many exceptions are known. In the case of typhoid and influenza one is not left immune from future attacks; indeed, in a very short time one is susceptible to a second attack. Certain people are naturally immune to many diseases. The absence of such immunity or resistance, which may be total or partial, characterizes what is known as *susceptibility*.

Throughout the human family, as well as the animal and plant kingdom, there is a great variation in the degree of

immunity and susceptibility to the various bacterial and protozoan diseases. Some individuals possess a high degree of immunity, and thus they appear to be free from the attacks of disease-producing bacteria. In others the degree of immunity is so low that they fall a prey to the ravages of any and all disease-producing organisms—that is, they have a high degree of susceptibility.

Hygiene and Sanitation.—A person may be immune to a disease, for the reason that his blood is able to produce the necessary antitoxin, or that the blood contains substances that are fatal to the life of attacking bacteria. It must not be thought, however, that any one person is ever perfectly immune from all disease attacks. In many instances immunity is dependent upon the state of health. An individual who is able to maintain a high state of health is not so susceptible as if he were in a poor state of health. A condition of bodily health is dependent upon two factors: (1) the personal factor and (2) environmental factors.

The personal factor determines the kind of care that is given to the body and the various parts of the body. The personal factor is largely determined by a set of habits, proper or improper, good or bad, healthful or unhealthful. Such habits have to do with personal cleanliness, sleeping in the open air, living in properly ventilated rooms, and having a carefully selected diet, proper clothing, sufficient sunlight, recreation, hours of sleep and rest, and the proper mental attitude. The sum total of all the habits concerned with the care and the use of the body is called *personal hygiene*. *Hygiene is the science of right living*.

The environmental factors arise from the individual's surroundings. Bad climate, neglected ventilation of sleeping and living rooms, impure supplies of water and milk, unclean air, germ-laden meats and other foods, contagious diseases, excessive heat or cold, accumulations of filth that send forth odors and disease-producing bacteria, and many other factors make up the conditions that determine the environment as unfavorable.

Organized efforts that provide for community cleanliness and safety are concerned with the preservation of health.

That science which has to do with the preservation of health is known as *sanitation*. Consequently the science of sanitation brings into use the best methods of sewage disposal, water purification, street cleaning, securing and marketing food, stamping out contagious diseases, and similar activities related to community welfare.

From what has been said, it may be well inferred that *personal hygiene* is concerned with the health of the individual, while *sanitation* or *domestic hygiene* is concerned with the health of the community. No such sharp distinction can be made between the two branches of the health sciences, for in many instances the problems of one are also the problems of the other. For a city dweller the habit of bathing is a personal matter, but the purity of the water that he uses for drinking and bathing has been determined by the community in which he lives. Personal habits on the part of the individual may be such as to lead to the contraction of a contagious disease, and consequently the community is concerned.

Infection ; Infectious and Contagious Diseases.—It is hardly necessary to emphasize the fact that no one can contract a microbial disease unless he comes into contact with the particular microbe which causes that disease. When a disease-producing microbe enters and inhabits a plant or animal body and there multiples to such an extent as to do injury, the plant or animal is said to be *infected*. An *infectious disease*, then, *is any disease that results from the presence of microbes in the body of an animal or plant*. A *contagious disease* is an infectious disease which is transmitted from one to another by contact. That is, the term *infection* refers to the *cause of the disease*, while the term *contagious* refers to the *method of transmission*.

Droplet Infection.—It was at one time thought that in diseases such as smallpox, measles, scarlet fever, a nd diphtheria, the infectious microbes might be carried through the air after being deposited on clothing and fnrnishings. However, recent investigations have shown that this method of transferring infection is comparatively rare, and that most infections are transmitted by direct contact. However, it is known that the infectious micro-organisms may be carried on small

particles or droplets of sputum or moisture. These instances of aerial infection are known as *droplet infection.* (Marshall 1921.)

In this connection it has been demonstrated that during the act of talking, coughing, and sneezing, small droplets or bubbles of sputum are thrown out into the air. The distance that these small particles may be carried is surprising. It is stated that they are frequently thrown out fifteen feet or more. In connection with tuberculosis it has been shown that the *bacterium tuberculosis* is rarely thrown out over four or five feet by the cough of the tuberculous individual. These bacteria will, however, remain alive two or three weeks when in the dark, but they live only a few hours in the sunlight. Diseases that are commonly spread about by means of droplet infection are whooping cough, mumps, influenza, measles, pneumonia, and meningitis. This type of infection occurs in crowded quarters, such as dark shops, schools, tenements, street cars, and railway trains.

Infection from Food and Water.—Infections resulting in typhoid fever may arise from foods, water, or soil. The micro-organisms of typhoid fever have been known to remain alive for a year in soils rich in organic material. The length of time that these and other organisms remain alive in water depends greatly upon the presence of organic substances. In relatively pure water most of the disease-producing bacteria are able to live but a few days. Consequently vegetables grown in soils or washed in waters contaminated with typhoid germs become carriers of this disease.

Likewise milk containers, dairy implements, and household utensils washed in water bearing typhoid germs impart the bacteria of this disease to dairy products and food materials. Milk, shell fish, and oysters are frequent carriers of typhoid bacteria which they may receive from dairymen, fishermen, and handlers, and from unclean containers of every kind. Meats and fish which have been acted upon by bacteria contain the poisonous wastes thrown off by the micro-organisms. When such meats or fish are eaten, the bacterial excretions give rise to an infection known as ptomain poisoning.

Animal Carriers of Infection.—Animals may communicate disease-producing germs to one another and to man in three ways. The first is by direct contact, which is well illustrated by

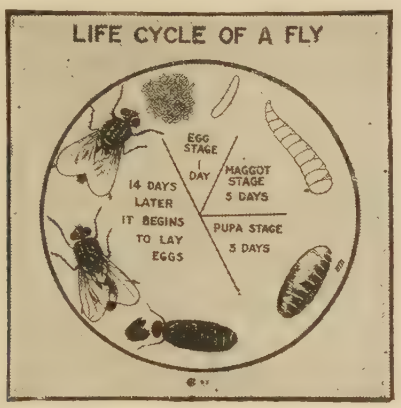


FIG. 308.—The life cycle of the fly. (*Courtesy of International Harvester Co.*)

the communication of tuberculosis to man by cattle; of rabies, by dogs; and of anthrax, by sheep.

Secondly, animals may serve as mechanical carriers from one individual to another. In this instance insects are the chief

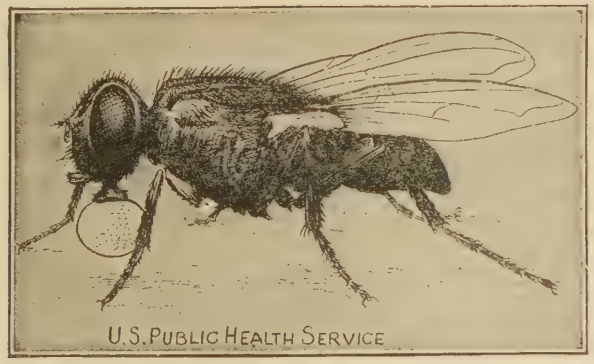


FIG. 309.—A fly regurgitating food and bacteria. (*U. S. Public Health Service.*)

offenders. Common flies frequently carry the typhoid bacteria on their feet, from which the bacteria are transferred to food materials, and thus cause infection when the foods are eaten. The flies obtain their loads of bacteria from the typhoid patient,

or the sputum, or excreta of a person so infected. Tropical flies, wood ticks, fleas, and lice, all of which withdraw blood from the tissues of man or animal, may serve as carriers of disease-producing germs.

Thirdly, an animal may serve as a host and as a carrier of the infecting organism. As an example we have already considered the mosquitoes in which the micro-organisms of malaria and yellow fever spend a portion of their life. (See Chapter XIV, Mosquitoes and Disease.)

Human Carriers of Infection.—Very frequently persons who have had typhoid fever continue to carry large numbers of virulent typhoid bacteria and to give them off continually in intestinal wastes. Such wastes frequently find their way to water supplies which, when used for drinking or household purposes, give rise to many infections. It has been repeatedly shown that man is capable of carrying infectious germs when he himself is not infected. For instance, in the case of diphtheria, persons who have had diphtheria and persons who have never had the disease frequently carry very virulent forms which they are continually disseminating by means of nose and mouth excretions. Individuals who carry infectious organisms are properly known as "bacilli carriers" and should be kept under rigid quarantine or observation.

The Control of Infectious Diseases.—The control of infectious disease is all based upon two fundamental facts: (1) *that an infectious disease can arise only from the presence of a particular microbial agent*, and (2) that *the spread of the disease depends upon the passage of the microbial agent from patient to prospective victim*. To prevent the broadcasting and the general transmission of disease-producing organisms from patient to prospective victim, three well-defined means of control should be established.

The first means of control consists in *establishing one or more barriers* about the infected person for the purpose of confining the disease-producing agents. The barriers consist of measures that have to do with personal hygiene; personal habits of cleanliness, medical treatment, disinfection and proper disposal of wastes, disinfection of clothing and contact materials, report

THE TRANSMISSION AND THE MEANS OF PROTECTION AGAINST TRANSMISSION OF MICROBIAL DISEASES

From the patient	Routes and means of travel for microbes at large	To prospective victim
Third barrier established by public authorities		First line of defense established by public authorities.
Cause and measures of prevention. Supervision of disinfection and disposal of wastes. Enforcement of quarantine, and isolation.	By raw vegetables By fruits By shellfish	General sanitation. Removal of manures, garbage, filth, and materials favorable to the breeding of flies. Purification of water supply. Inspection of garden truck, milk, meats, fish. Supervision of public and private wells and vended spring waters, etc.
Second barrier established by the household	By water	Second line of defense established by the household.
Cleanliness in the sick room. Disinfection of wastes, clothing, used bath waters, sponges, towels, napkins, bedding. Screens to prevent the visits of flies to house and vaults. Respect for quarantine.	By milk By contact By flies By mosquitoes	Cleanliness in the kitchen. Boiling water, sterilization of milk and utensils. Care of wells and cisterns. Care as to source of foods. Screens for house, stable, and vaults. Covers for garbage cans. Clean yards.
First barrier established by the physician	By dust or droplets	Third line of defense established by the individual
Medical treatment. Examination of wastes, blood, etc. Instruction as to disinfection and disposal of wastes. Report to the Board of Health.	By various means unknown	Personal cleanliness. Avoidance of exposure. Proper selection of foods. Practices that are conducive to good health, such as proper hours for work, recreation, and rest. Plenty of fresh air, abundance of sunlight, and right clothing materials.

to board of health, and obedience to regulations concerned with quarantine and isolation.

The second means of control consists in *cutting off all means and routes of travel by which the disease-producing organism might pass from patient to victim.* That is, measures should be taken to prevent the germs from passing from patient to victim by means of contaminated foods, by water, by flies, by contact, etc.

The third means of control consists of *measures of defense* which have to do with the prospective victim. The defensive measures are concerned with habits of personal hygiene: personal cleanliness, avoidance of exposure and contact, proper selection and preparation of foods, recreation, and rest.

Projects

1. To learn how to pasteurize milk in order that the art may be put to practice in the home. Report method of procedure step by step.

2. To learn the art of preserving foods by sterilization and canning. Report purpose, method, and experiences for one fruit or vegetable. Display the sample.

3. To make a study of the arts and practices relative to dairy products.

Suggestions.—Visit dairy farms, creameries, pasteurizing and bottling stations. Are sanitary practices the habit? Report means used to secure clean and pure milk, or the lack of habits of cleanliness. Many dairy associations and Experimental Stations have a full set of lantern slides showing all activities from producer to consumer. Secure the slides, and become familiar with the purpose of each. Make arrangements to show and describe the slides.

4. To visit a canning factory in order to observe the various processes that are employed in preparing and sterilizing the articles of food and sealing them in containers.

Make a written report giving details of the process, special means that insure cleanliness and wholesomeness of foods, and other items of interest.

5. To examine the various labels of canned foods and to learn whether there is a statement concerning the presence of chemical preservatives. Report your findings and that section of the national food law concerning the proper branding of foods that contain chemical preservatives.

6. To learn what department of the city government is concerned with the inspection of foods, and the nature of the activities that result in the proper inspection of foods.

7. To learn the names of the diseases that the local board of health requires to be quarantined, and the extent of the quarantine in each case.

8. To show how a Board of Health goes to work to discover the source of typhoid bacteria when cases of this disease occur.

9. To learn what is meant by *vaccination* and *inoculation*, and the purpose of each.

10. To investigate the various methods that are employed to exterminate flies and rats, in order that the best methods may be put to use in the home, warehouse, store, mill, factory, etc. Make a written report of methods and results.

11. To conduct a campaign in the community for the purpose of exterminating rats and flies.

Suggestion.—Write articles for the press. Distribute circulars. Obtain the coöperation of the Board of Health and similar organizations.

12. To make a visit to a pond for the purpose of observing and studying the relationships of the many forms of aquatic life.

Suggestion.—Look for instances which exemplify the conditions that determine "a balance of life." Are forms of algæ present? Are there evidences of the work of bacteria that cause decay?

13. To make a field trip for the purpose of observing the habits of various kinds of fungi—mushrooms, toadstools, shelf fungus, and the cluster-cup stage of rusts that are common on elder, crowfoot, barberry, Indian turnip, etc.

Make a written report in which the plants are classified as saprophytes or parasites.

Are molds and rusts of any economic importance?

If desirable, display specimens.

UNIT III

MAN, THE HIGHEST TYPE OF ORGANISM

The Power of Protoplasm to Organize Itself; Artificial Environment and Its Relation to Health.—In the world of plants the oak tree is a wonderfully constructed organism consisting of roots, stems, leaves, and flowers. In the same plant world exists the simple pleurococcus. In the oak tree millions of cells are in existence, while in the pleurococcus there is but one. The great and massive oak is the result of the labors of countless millions of cells which are thoroughly organized into well defined groups or tissues. The minute pleurococcus is the result of a single cell which is so organized as to perform all the labors within itself. While the oak and the pleurococcus tell us nothing about the mystery of protoplasm, they do exemplify in a wonderful way the ability of protoplasm to organize itself into one-celled or many-celled organisms.

In the animal world we find individuals made up of wonderfully organized groups of cells, and individuals that consist of but a single cell. Man exemplifies the highest type of organized cell groups, while the formless amœba represents the most simple of the one-celled type. Since early in life we have learned much about the mystery of ourselves and the animal forms that we see about us. We know that man, beast, bird, and fish are all provided with bones, muscles, nerves, blood vessels, digestive apparatus, protective coverings, and means of getting about more or less rapidly from place to place.

In addition to this we know that the higher forms of life all possess highly organized nervous systems, which cause an animal to be more or less sensitive to his surroundings—to his environment. In this connection man is more highly organized than any other animal. Above all other animals man possesses a nervous organization that permits him to judge, to reason, to

will—in short, to design by means of mental processes. The fish, the eagle, or the fox must find food in the range of his environment. Man designs boats, railroads, systems for telegraphing, and systems of exchange, and thus he is able to bring to his table the many foods of the earth. Man constructs homes in which the water, the air, the heat, and the light are all regulated and governed by artificial means. And thus, unlike the beasts, or the birds, or the fish, man controls to a greater or less degree the five great environmental factors—water, food, air, heat, and light.

With this ability to enlarge and to regulate his environment one would conclude that the general condition of man's health would always be at its best. Such an ideal state of affairs is seldom, if ever, in existence. One person may live in a well lighted, correctly ventilated, and heat-regulated home, but suffer indigestion and a low state of health arising from contaminated water, or the selection of improper foods, or an immoderate use of rich foods. Poor air, too much heat, extending the work day or the social hour into the hours of darkness because of artificial light, etc., all tend to lessen the proper working of the many systems that compose his body.

Man, like the oak, is the result of the labors of many groups of cells. Nature has so nicely adjusted the nerves, the muscles, the bones, and other organs and systems within the body of man that he is seldom aware of their presence. Broken down nervous systems, exhausted muscles, impaired lungs, or defective digestive processes unbalance the nice adjustment that nature designs. Most of the upsetting of bodily adjustments come about because of man's ignorance of himself. In order to live well, all the cell groups must be at their best. In order that we may appreciate and properly care for the wonderful organization of the several systems that make up the body, this unit is concerned with study of cell organization as it occurs in the human body.

CHAPTER XXVI

THE DEVELOPMENT OF TISSUES, ORGANS, AND SYSTEMS, AND THEIR ORGANIZATION INTO A LIVING UNIT

Object.—To investigate one of the most remarkable tendencies on the part of protoplasm—the tendency to organize itself for the purpose of building up higher forms of life.

Nature Provides for a Division of Labor.—In the human affairs of a great city the people are engaged in many kinds of labor. Some are keeping shops or banks, some are shaping stone or wood or molding bricks, some are writing and publishing newspapers and books, some are professionally engaged in medicine or law or teaching, and some are guarding or protecting the lives of people. The occupations are varied and numberless. The sum total of all the different kinds of labor results in a successful city.

The same thing is true when we visit a large factory in which a machine or a material is being manufactured. One group of men is busy with raw materials. Another group of men is concerned with the making of a certain portion of the machine, a second group with another part, and so on for each and every part that is essential to the machine. Finally, other groups of men bring the parts together and assemble them. The machine leaves the factory complete and ready for service.

In the city and in the factory we find no one man able to do all the work. Each individual or group of workers performs a particular labor and performs it skillfully and well. This division of work among men, or groups of men, is known as *the division of labor.*

Nowhere is the division of labors put to practice on a greater and a grander scale than it is in nature. Each and every complex plant and animal body is so constructed and organized as to provide for the performance of the many different labors that are essential to the continuance of life. Examine a flowering plant and observe its natural divisions—root, stem, leaf,

and flowers. The difference in their forms and structures suggests a difference in the nature of the labor that each performs. Examine closely the leaf or the flower. In each there are many differing parts and structures, each of which has its particular task or labors to perform. In short there is a *differentiation of parts* in the flowering plant. *Differentiation of parts* is essential wherever there is to be a *division of labor*. For instance, root hairs and stamens are greatly differentiated for the purpose of performing greatly different labors—gathering moisture and producing pollen. A differentiation of parts and a division of labor go hand in hand as we pass from the simple to the more complex plant or animal.

In this connection it must not be forgotten that all plants and animals start life as single cells. No tree or bird or fish or beast comes into sudden existence. In the flower the union of the pollen grain and the ovule produces the fertilized egg-cell. When the fertilized egg-cell divides, the new cells do not separate as in the pleurococcus but form a mass of cells by clinging together. As the processes of growth take place, more cell-divisions occur. Finally the mass becomes greatly enlarged. Since some cells are always external while some are internal, the forces acting on the mass produce conditions which do not allow all the cells of the mass to remain long alike. As time passes, the differences become more and more deep seated, and a seed comes into being. Within the seed is the miniature plant constructed of miniature parts composed of minute structures. During germination the baby plant grows, and the adult plant comes into existence with its many differentiated parts.

The fertilized egg-cell of the oak tree invariably gives rise to an oak, the fertilized egg of the frog produces the frog, the eagle develops from a fertilized egg of an eagle, and thus it is for each and every complex organism of any kind whatsoever. The change from fertilized egg-cell to the complex adult is not a sudden one. The building up process is slow and proceeds step by step from tissues to organs and then to systems. This property of protoplasm to organize itself is beautifully characterized in all the living forms that exist about us and is, indeed, the fundamental basis of our own human existence.

THE HYDRA; TISSUES

Object.—To observe a hydra at work in order to become familiar with the structure, the arrangement, and the work of tissues.

APPARATUS.—Microscope. Cover glass. Glass slide. Watch glass. Two one-gallon jars.

MATERIALS.—Jars containing pond water and hydra. Small fragments (size of a pin-head) of meat or boiled egg.

PROCEDURE.—1. Hydras are small tubular animals furnished with 6–8 tentacles (Fig. 310). They may be found in permanent fresh water pools attached to submerged stems, leaves, twigs, algæ, etc. While in the ponds they are hard to locate, for when disturbed they contract so greatly as to be difficult to recognize. Therefore gather several leaves, stems, or sticks from several portions of a pond in which hydra are most likely to occur. Place them in a jar of pond water. After a few moments of quiet, observe the surfaces of the collected materials for the presence of extended hydra. The hydra occur in all parts of the country and provide a wonderful opportunity for the study of the cell grouping and the differentiation of tissues for the division of labor. There are two kinds of hydra, the green and the light brown. The green hydra are so colored because of the green algæ which their several cells have taken up. Hydras have no chlorophyll. The brown hydra is more transparent and more easily studied. The fragments bearing hydra should be transferred to a jar of pond water and thence to the laboratory for further study.

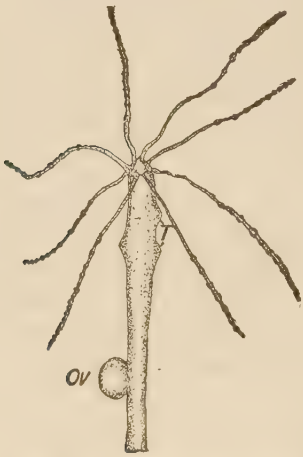


FIG. 310.—Fresh water hydra. *Ov*, Ovum; *T*, prominences containing sperms. (*From Holmes' Elements of Animal Biology.*)

2. Remove a fragment bearing a hydra. Place the fragment and hydra in a watch glass of water. Observe and study the movements and habits of the animal. Observe the shape and form when extended and when contracted. Observe the movement on the part of the tentacles. Do you see any reason for any or all of these forms of motion?

3. Is the hydra free or attached? Is it heavier or lighter than water? How do you know? Can it move from one part of the vessel to another? (Observe a given individual from day to day and discover changes of position.)

4. Do the animals collect on the dark or light side of the jar? Are they sensitive to light?

5. When one of the hydras is fully extended, touch lightly one of the tentacles. What happens? Touch the body. What happens? Is the animal sensitive to the presence of objects?

6. Bring a piece of meat (size of pin-head) in contact with the tip of a tentacle. Explain all that happens. Do the other tentacles come to the assistance of the one discovering the meat? Place a food particle near that portion of the body where all the tentacles join the body. What happens? Repeat with particles of sand or glass. Is the hydra able to select food materials?

7. Summarize all the activities of the hydra under the following: motion, sensation, selection of foods, nutrition, etc.

8. Transfer a living hydra to a glass slide. Cover it with one or more drops of water. Without a cover glass observe it with the low power of the microscope. Observe everything and compare what you see with that indicated in Fig. 313. Is the body hollow like a cup, or solid? Are the tentacles solid or hollow? Are there any buds on your specimen (see Fig. 310 and Fig. 313)? What is the purpose of the buds?

9. Do you observe any instance in which there is a division of labor among the cells (see Fig. 313 and read text)? Why does the hydra contract when disturbed? Is this a protective measure? Is the outer layer of cells better able to provide protection than the inner layer? Does the inner layer digest the food and pass it on by osmosis to the outer layer? Is there a differentiation of cells? A division of labor?

10. Is the hydra well adapted to a life in water? How does it secure its supply of oxygen? How does it circulate its food? Why are not ponds and lakes overrun with hydra?

11. Report all your observations, reasons, and conclusions in the form of a brief theme.

THE EARTHWORM. DIVISION OF LABOR AMONG TISSUES

Object.—To make a study of the tissues in the body of an earthworm in order to learn how tissues are adapted to the performance of special labors.

APPARATUS.—Shallow dish or tray. Hand lens.

MATERIALS.—Sand or blotting paper. Live earthworm.

PROCEDURE.—1. In a shallow dish place a layer of sand or blotting paper. Moisten with water. Place an earthworm on the sand.

2. Is the worm active or sluggish in its movements? Identify the *anterior* (fore end) from the *posterior* end. In what manner does the *dorsal* (back) surface differ from the *ventral* surface? On which surface does the worm crawl?

3. The body wall of an earthworm is composed of two sets of muscular tissues that lie just below the skin. One set of muscles passes in a circular direction about the body, while an inner set runs lengthwise. Hence there are two muscular tissues that compose the muscular walls of the earthworm. (See Fig. 311.)

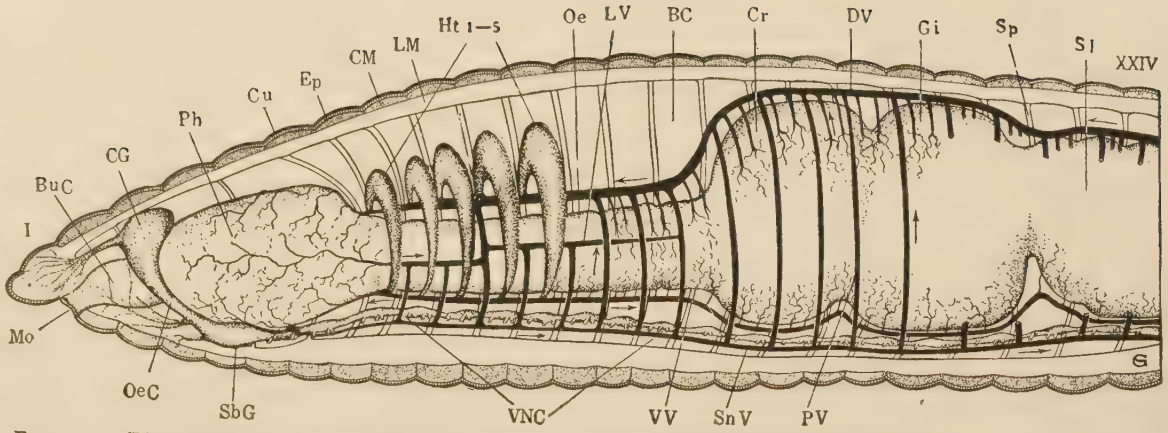


FIG. 311.—Diagram of the anterior end of an earthworm to show the digestive, nervous, and blood systems. (*From General Zoology Laboratory Directions by Sigerfoos.*)

BC, body cavity
BuC, mouth cavity
CG, brain
CM, circular muscles
Cr, Crop
Cu, Cuticle
DV, Dorsal blood vessel
Ep, Epidermis
Gi, gizzard
Ht, five pairs of hearts
LV, lateral vessel
LM, longitudinal muscles
Mo, mouth
Oe, esophagus
OeC, commissure
PV, parietal vessels
Ph, pharynx
Si, intestine
Sp, septa
SnV, subneural
SbG, sub-ganglion
VNC, nerve cord
VV, ventral vessel
I–XXIV, segments

Observe the worm as it crawls. Which of the muscular tissues pulls the body together in order to shorten it? When one set of muscles contracts, the other set of muscles must relax. When the worm lengthens itself, which set of muscles contracts and which set relaxes?

4. Examine closely the dorsal surface and see if you can locate a red tube lying just below the surface of the body wall of the worm. In very young or half grown worms the tube is easily seen, in which case the blood may also be seen pulsating through the tube. This red tube is the dorsal blood vessel. In what direction is the blood pulsating—toward or away from the anterior end? Consult Fig. 311 and locate the dorsal blood vessel (*DV*), the five pairs of hearts (*HT*), the ventral blood vessel (*VV*), the subneural blood vessel (*Sn V*), and observe the direction in which the blood flows as indicated by the arrows. Has the earthworm a well organized circulatory system?

5. Cover one half of the dish with a book. Does the worm seek the light or the dark? Is the worm sensitive to light? Consult Fig. 311 and locate the brain (*CG*), the nerve ganglion (*SbG*), and the nerve cord (*VNC*). Observe that the brain lies at the anterior end and that the lip-like portion above the mouth is well supplied with nerves. For this reason the anterior end is far more sensitive than the posterior end. In the lip-like organ the sense of touch is very highly developed. In the skin at the anterior, biologists have discovered minute structures that are quite sensitive to varying degrees of light. The worm has no eyes nor ears. Its sense of touch is so well developed that any slight vibration disturbs it. Do you consider the nervous system in the earthworm well suited to the performance of its particular kind of labor? Is it sufficient for the needs of the earthworm?

6. Closely examine the mouth of the earthworm. Is the muscular and well formed lip-like organ well suited to pushing food (dirt) into the mouth? As the worm tunnels its way through the ground, it eats the loosened dirt, which is passed through the digestive cavity and excreted at the posterior end.

In Fig. 311 locate the mouth (*Mo*), the pharynx, the esophagus, the crop (*Cr*), the gizzard (*Gi*), and the intestine (*Si*). Many glands pour digestive fluids into the digestive cavity. These digestive fluids act upon the dirt, and thus the worm is able to extract organic foods from the ground through which it travels. Is the digestive system in the earthworm well organized? Is it sufficient to the needs of an earthworm?

7. Report only on the following: (*a*) Is the circulatory system so related that it can gather digested foods and distribute them to other systems?

(*b*) Is the circulatory system so related to the body wall (the muscular layers) as to be able to receive supplies of absorbed oxygen? Why do earthworms come to the surface when rains fill the soil with water? Do earthworms need more or less oxygen than more active animals?

(*c*) Is the nervous system so related and adapted as to keep all portions of the body in communication with the brain? Explain.

(*d*) Is the muscular system sufficient for the needs of the earthworm? Is it well organized into tissues? How are the tissues arranged so as to provide locomotion? Does the lengthening and shortening of the body during the process of crawling aid and assist the passage of foods through the food tube? Give reasons for your answers.

(*e*) Is the earthworm a more highly organized animal than the hydra? Explain by comparison and contrast.

FROM EGG TO ANIMAL

(*Arrange with instructor for regular periods of observation. This may be done as home work.*)

Object.—To observe the various stages of development that take place within an egg during the period of incubation.

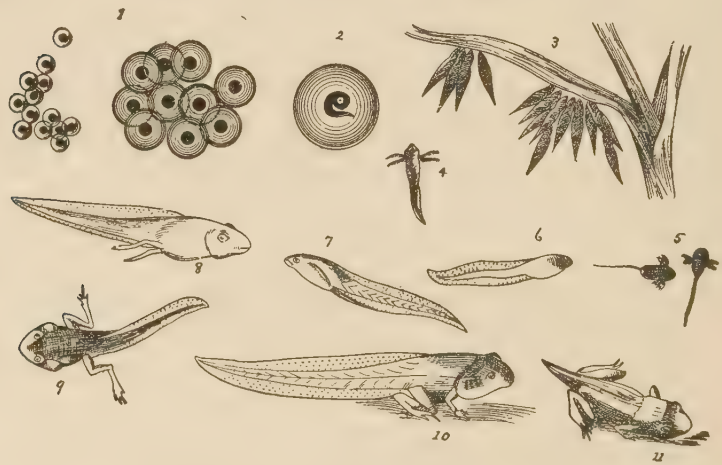


FIG. 312.—The life history of the frog, showing the stages through which it passes in developing from the egg to the adult. (*From Galloway's Text Book of Zoology. After Brehm.*)

APPARATUS.—Microscope. Watch glass.

MATERIALS.—Two or more aquariums provided with fertilized eggs of the frog, or toad, or the fish.

PROCEDURE AND OBSERVATION.—1. Place one or more of the eggs in a watch glass and examine with the low power of the microscope. Study the egg mass with a hand lens. Observe the yolk masses within masses of albuminous material. The yolk contains highly concentrated food materials and the fertilized egg-cell.

2. Observe the egg masses from time to time and note the state of development.

3. Movement occurs at an early stage, and changes of form are revealed by a good hand lens.

4. What is the purpose of the yolk in an egg? The albuminous substance about the egg? How does the developing embryo breathe? Is the embryo dependent for a certain length of time upon the food supply within the egg? What is the sole purpose of eggs? Is the purpose of eggs in animals the same as that of seeds in flowering plants?

5. Wrap the head and body of a tadpole in a moist piece of gauze and lay all on a glass slide so that the exposed tail lies flat on the surface of the glass slide. Place a few drops of water about the tail. Examine the tail with low power of the microscope and observe the circulation of blood and other fluids within the capillary tubes. Observe and study other details of structure. What is the purpose of circulating blood within animal bodies?

6. Report observations and conclusions in the form of a brief theme.

The Human Machine and Its Relation to Our Requirements. When a savage and a skilled civil engineer look at a steamship, their eyes and optic nerves convey about the same mental picture to the brain of each. But the interpretation of the mental picture by the two individuals is very different. The mind of the savage sees scarcely anything beyond the paints, colors, size, shape, arrangement of masts, funnels, and smoke stacks. The mind of the engineer is translating the picture from the standpoint of construction, materials, engines, horse power, capacity, cost of operation, and many other similar details. Briefly, the engineer's mind is able to go from external details to internal details. In the depths of his mind he can *see* through the ship and its several parts as though it were made of glass or some other equally transparent substance. The untutored mind of the savage can not *see* beyond the paint that covers the outside of the ship.

Concerning the structure of our own bodies we are very much like the savage looking at the painted steamboat. So long as we are able to get about, we think little or nothing of the make-up of the human machine. And so we continue day after day to practice habits of living that disturb the nice adjustments that exist among the several organs and systems that make up our bodies. At first nature is patient and labors to correct

the disturbed adjustments. Again we misinterpret things, and like a spoiled child we begin to think that nature will ever continue being charitable toward our flagrant ways. Finally, when the human machine breaks down, we call in the skilled expert, the doctor. He locates the breakdown or diagnoses the ill. He may pronounce it a case of nervous breakdown, muscular exhaustion, poor blood (anæmia), impaired digestion, a fever, or other malady.

However, the doctor can not undo the damage; he can advise us, and instruct us, and may require of us the performance of certain duties. The actual repair is brought about in *the cell* of the affected portion. If the several cells fail to respond to *treatment*, the breakdown is permanent. If they do respond, the breakdown, the disturbance, or the malady may be more or less removed. But in either case we have lost a portion of our grand heritage of life and action. Like savages we fail to see beyond the surface of things—especially of our bodies.

In the case of the savage a knowledge of self is quite unnecessary. Since he is the child of nature, nature cares for him. She provides his forest or mountain habitation with pure air, pure springs, pure food, sunshine, and other needs of his simple life. With civilized man it is greatly different. He forces the human machine to labors and habits of life that involve the ceaseless use of the nervous system. Physicians, editors, lawyers, teachers, bankers, bank clerks, civil engineers, scholars, and students in every field of science are *living by their wits* and are using their brains to an extent quite unknown even among men a century ago. Never has competition been so keen, never has the requirement of ability and skill been so high, never has the utilization of nature's resources been so far reaching, never has the organization of nature's forces to the performance of labor been so well directed, as they are today. Business men, professional men, mechanics, in short, men of every pursuit of civilized life find that alertness and well directed activity are essential to the merest kind of success.

The well organized means of communication consisting of newspapers, mail service, telegraph, telephone, railroads, motor vehicles, and airplanes have so speeded up the business and

industrial world that the human machine must of necessity be speeded up to meet the demands of our modern ways of living and obtaining a livelihood.

When an auto-vehicle fails to transport its loads or to perform the particular service required of it, we have it overhauled and put into proper condition. If we fail to have it overhauled, we replace the motor vehicle with a new one. With the human machine it is different. We can have it neither overhauled nor replaced with a new one. In order to keep the human machine in effective service it must be so maintained as to be in a high state of perfection. The process of growth and repair must always overbalance the processes that wear and destroy. The most remarkable thing about the human machine is the fact that it is a living organism. To keep the human machine in a high state of effectiveness, and at the same time to continue in active affairs of life, demands that we know how to take the best possible care of the delicate and intricate parts that bear the burdens of human requirements.

The Hydra, an Organization of Simple Tissues.—The best way to understand a machine is to see its several parts in operation, to study each of the operating parts, and to discover the relation of each of the parts to the whole machine. Our bodies are so encased that such a method of procedure is quite impossible. Fortunately there are in nature many animal forms so constructed that we are able to observe many of the tissues at work. Already we have seen protoplasm at work in the single cell in the form of the amœba, the paramecium, and the vorticella. The hydra is a many-celled animal, but so simply constructed that it consists of but two tissues. Since all protoplasm is essentially the same regardless of the animal form in which it occurs, biologists and physiologists find that the study of the cells, tissues, and organs as they occur in the lower forms is essential to their understanding of those in the higher forms.

The hydra is a little animal whose body is much like a hollow cylinder furnished at one end with a mouth which is surrounded with a varying number (6–8) of arms or tentacles (Fig. 313). The end opposite the mouth is called the foot, by means of which

the hydra attaches itself to objects. The attachment is not permanent, as the hydra is able to free itself and make its way to another locality. When disturbed it contracts to a very minute size. When it is expanded the tentacles reach out almost an inch in search of food which they conduct to the mouth.

The structure of the hydra is very simple. The sac-like body is composed of two layers of cells separated by a thin

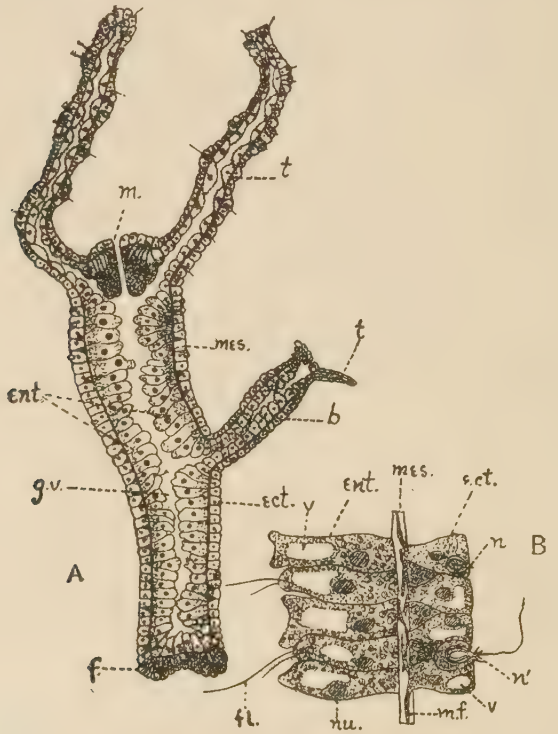


FIG. 313.—*A*, Longitudinal section through the body of a hydra. *B*, Small portion of body wall more highly magnified. *b*, Bud; *ect*, ectoderm; *ent*, entoderm; *f*, foot; *mf*, muscular process of the ectodermal cells; *n*, stinging cell; *n'*, same extended; *nu*, nucleus; *t*, tentacle; v, vacuole. (*From Galloway's Text Book of Zoology.*)

membrane. The outer is known as the *ectoderm;* the inner, as the *entoderm*. The ectoderm covers the entire outer surface of the hydra, while the entoderm lines the digestive cavity within the body and the tentacles. The cells of the entoderm pour out digestive juices which act on whatever foods are brought into the body cavity. The digested foods are absorbed

by the cells of the entoderm and passed by osmosis to the cells of the outer layer or ectoderm. Often the cells of the entoderm take small particles of food from the digestive cavity and complete the digestive process within their walls. Indigestible substances and waste materials are expelled through the mouth. It is clear that cells that compose the entoderm have a special labor to perform—the digestion of foods. The entoderm is a *digestive tissue*—a very simple digestive system consisting of but one layer of cells. Since it passes the prepared foods from cell to cell, it also serves as a crude circulatory system.

The ectoderm serves as a protective tissue to the more delicate cells that compose the entoderm. Many cells of the ectoderm are armed with stinging devices. Especially is this true of many cells found in the ectoderm covering the tentacles (Fig. 313). The stinging cells contain a poisonous irritating fluid which serve to paralyze the little animals upon which the hydra feeds. Thus the ectoderm is well provided and properly fitted to serve as a *protective tissue*. Not only does the ectoderm provide protection, but it must serve as a muscular tissue, as a nerve tissue, and as a reproductive tissue. Consequently when one part of the body communicates with another portion, it is the ectoderm that serves as a crude nerve. When it is necessary for any movement to be brought about, it is the ectoderm that serves as a crude muscle. Thus we see a tissue capable of performing three labors—protection, communication, and motion. In higher animals highly specialized nervous tissues transmit all communications and control the action of muscles, and the muscles are so arranged as to protect the more delicate parts.

Reproduction in the hydra is brought about in two ways: (1) asexually, by the formation of buds (Fig. 313); and (2) sexually, by means of sperms and eggs. In the budding process both layers push outward in the form of a tube, tentacles are produced about the outer end of the tube, and a mouth comes into existence. Finally the base of the bud closes, and a new hydra has come into existence. In the second instance the sperms and eggs are produced in the same individual. The eggs are produced, one or two at a time,

near the base of the body (*OV*, Fig. 310). The sperms are produced in slight projections near the mouth end of the tube (*T*, Fig. 310). The sperms are set free in the water and travel to the egg (ovum), which they fertilize. The fertilized egg remains in its cavity in the body wall until it has developed a protective and spiny shell. The egg is then discharged and lies at the bottom of the pond until a time when conditions are favorable to its awakening and growth. The egg is highly resistant and can withstand periods of drought and other unfavorable conditions. In this manner the hydra is able to continue its kind from period to period.

The Earthworm, an Organization of Simple Systems.—The simply constructed hydra solves all the problems of life with two tissues. Its manner of living is extremely simple, yet it is more highly organized than is either the paramecium or vorticella. The hydra appears to be more aggressive than the one-celled forms of life, and is better fitted to take advantage of the food supplies that exist in its environment. Not only does the hydra feed on many foods used by the one-celled animals, but it is continually capturing and devouring the simpler organisms. The superiority of the hydra over the one-celled kingdom arises from its degree of organization in which the labors of securing a living are divided between the two groups of cells. Thus the cells in the hydra are not "jacks of all trades" but specialists in the performance of a few. The purpose of organization is to bring about a certain degree of specialization through a division of labor.

On examining the earthworm we find it to be more highly organized than the hydra. In the place of single tissues as in the hydra, we find the earthworm has groups of tissues—*organs*—set aside for the performance of a single labor. We find furthermore that the organs are combined into systems in which the combined work of the several organs brings about the performance of required labors. The muscular system and the nervous system are so closely related (coördinated) that the movements of the worm are well directed, and thus the worm is able to move rapidly from unfavorable environments to those more favorable.

The digestive system of the earthworm is in many respects quite as well organized as that found in higher forms. While the mouth is not fitted with teeth, the muscular *pharynx* (see Fig. 311) is able by suction to draw in the required materials in which food occurs. Then follows a well developed *esophagus*, which conducts the food into a thin-walled crop. From the *crop* the food passes into a thick-walled gizzard, which grinds the food and mixes it well with secreted juices received along the route. The foods thus prepared are delivered into the intestine, where the digested materials are absorbed and the wastes are passed on and finally excreted.

Enveloping the entire digestive track is a well organized system of vessels for the circulation of blood. Numerous small blood vessels everywhere connect with the digestive canal and gather up the absorbed foods, which are then conveyed and distributed wherever needed. Five pulsating hearts keep the blood flowing in a definite direction through the blood vessels.

In order that the circulatory system, the digestive system, and the muscular system may all be in communication and work in harmony, there is a well developed nervous system coupled up with a brain. While the brain is not provided with eyes and ears for seeing and hearing, the worm is very sensitive to all degrees of light and possesses a sense of touch that is aware of the slightest disturbance of the ground upon which it lies. Thus as we walk over ground from which earthworms are protruding, they quickly withdraw into their tunnels.

A study of the earthworm reveals to us the nature and the purpose of organization in cells and tissues in an animal body. The success of a many-celled organism depends upon the labors of highly specialized groups. The sum total of all the labors of all the groups results in life and the continuance of life for the animal form in which the organization exists.

Types of Cells.—The earthworm exemplifies in a most wonderful way the manner in which cells are grouped into organs and systems, and the whole arrangement is installed within an animal body. In this relation it must be remembered that in order for a cell to be able to perform a special labor it must be fitted or suited to the particular service that it is required to

render. For example, a nerve cell has a form well fitted to the transmitting of communications, while a muscle cell is so constructed and formed as to produce powerful contractions. The essential contents of these cells are quite the same—protoplasm and substances which protoplasm builds up. Yet it is clear, from the different kinds of work that the cells do, that there are some deep-seated differences in the protoplasm. (See Fig. 314 and note the form and structure of the various

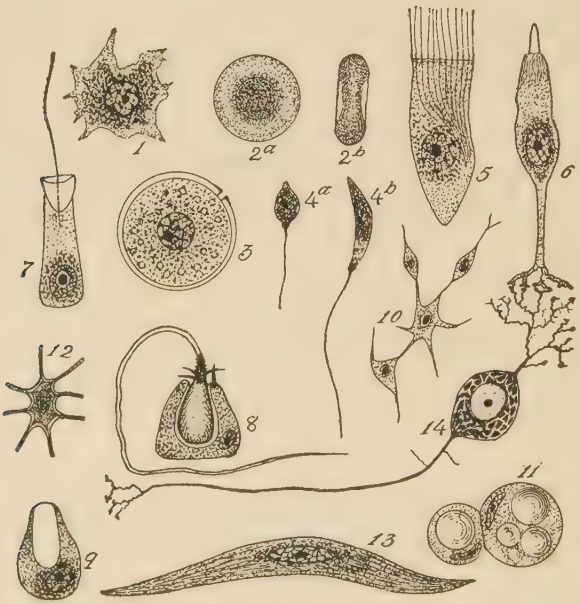


FIG. 314.—Types of tissue cells. (1) White (ameboid) blood cells. (2) Red blood cells. (3) Ovum. (4) Sperm cells. (5) Ciliate epithelium. (6) Sensory epithelium (from retina of the eye). (7) Flagellate (collared) epithelium. (8) A nettling cell from a hydra. (9) A mucus glandular cell. (10) Connective-tissue cells. (11) Fat cells. (12) A bonecell. (13) An unstriate (plain) muscle cell. (14) A ganglion (nerve cell) with its branches. (*From Galloway's Elementary Zoology.*)

types of cells that are used in building up the many kinds of tissues.)

In the case of modified cells it must not be thought that because cells are grouped into tissues the individual cell has no individual labors. The modified cell which makes up a tissue has its individual work, just the same as a simple and an independent cell. That is, while it does not perform all the

labors, it must do more of a certain kind of labor. It is the united work of all the cells that makes the life of the organism.

Tissues That We Have Seen.—Those of us who have examined pieces of boiled meat and stripped off the fibrous masses are already familiar with the nature and arrangement of muscular tissues. In tearing away fibrous structures it is more than likely that some of us who have sharp eyes have observed a kind of "connective" tissue that holds the threads and fibers in place. In meats that are boiled the connective tissue does not appear to offer a great deal of resistance. Connective tissues are composed of cells which are held together by a cement-like substance that lies between each and every cell. During the boiling process the cementing materials are broken down, and thus the fibers of flesh are easily separated. When we attempt to strip the muscle fibers from uncooked meats, we appreciate the tremendous resisting qualities of connective tissues.

Again, most of us have been served with chicken or turkey legs which we have dissected during the course of the meal. While making the dissection we must have observed the definite arrangement of the muscles, the bundles of muscles bound with connective tissue, the relation of muscles to tendons, the manner of attachment to bones and cartilages, blood vessels, and perhaps we have recognized the nerve cords running through the back bones of animals. Others of us have cleaned game, such as fish, fowl, and rabbits, and while doing so we have observed the uses of tissues—for holding the skin layers to the underlying flesh, lining the body cavities, covering internal organs, and holding the several organs in place. Thus on many occasions we have all observed and studied, more or less closely, the structures of animals, and as a consequence we are familiar with the appearance and the purpose of many kinds of tissues, organs, and systems of organs that make up the animal body.

Kinds of Tissues.—The tissues that are used to build up the various organs and parts of the body may be divided into the following groups: (1) epithelial tissue, (2) connective tissue, (3) muscular tissue, and (4) nervous tissue.

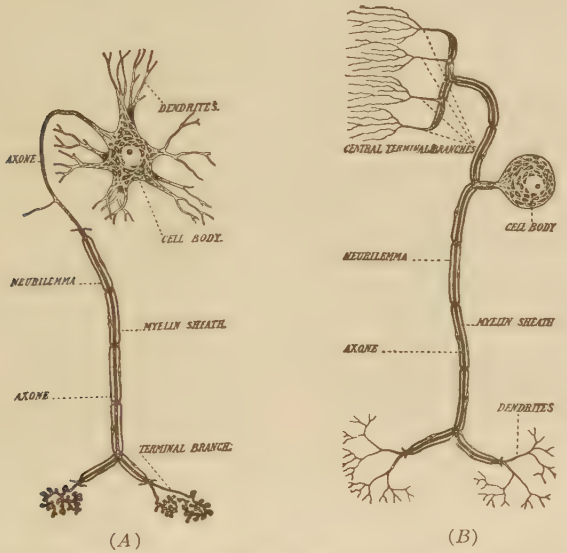
Epithelial Tissues.—The epithelial tissues include those which form the covering of the body, the lining of the nose, mouth, throat, respiratory and digestive tracts. They are composed of cells and a cement-like substance that holds the cells together. They contain no blood vessels and no nerves. The epithelial tissues rest upon other tissues from which they draw food supplies. Since epithelial tissues must render services that are best suited to the parts which they cover, there are as many kinds of epithelial cells as there are different labors to perform.

Connective Tissues.—The connective tissues like the epithelial tissue are composed of cells and cell cement. In order that connective tissues may perform the services required of them, they have the cell cement in greater abundance than they have cells. The bone-corpuscle, the cartilage-cell, the tendon-cell, and the connective tissue-cell are all essentially identical.

Muscular Tissues.—The chief characteristic of muscular tissue which distinguishes it from all other tissues is its property of contractility. There are three well known classes of muscular tissues. (1) The striated (striped) or voluntary muscle is used to build up the muscular systems attached to the skeleton. It also occurs in the tongue, pharynx, larynx, diaphragm, and in the walls of the abdomen. (2) The smooth or involuntary muscle occurs in bundles and thin sheets, and is used to build up the walls of blood vessels, the digestive tract, ducts of glands, eye lids, skin layers, etc. (3) The cardiac or heart muscle is used for the sole purpose of building up the heart. The muscle is striped like a voluntary muscle, but it is involuntary like the smooth or plain muscle.

Nerve Tissue; the Nerve Cell; Sensory and Motor Nerves. A discussion of nervous tissue is simply a discussion of the nerve cell itself. Like any other cell the nerve cell consists of cytoplasm and a nucleus. The body is more or less irregular and possesses several delicate thread-like projections. One of these thread-like projections is much longer than the others; it is the essential part of the nerve and is known as the *nerve process* or *axone*. (Fig. 315). The axone extends from nerve centers to muscles or to sense organs. Some of the axones are of considerable

length; those extending from the spinal cord to the muscles in the feet are over a yard in length and less than $\frac{1}{1000}$ of an inch in diameter. The nerves which carry messages from the sense organs to the nerve center are called *sensory* or *afferent* (to carry inward) nerves, while those that carry messages from the nerve center to the muscles are called *motor* or *efferent* (to carry outward) nerves. Nerve centers occur in the brain, in the spinal cord, in nerve enlargements (ganglia), in the connective tissue, and in many organs of the body, such as the heart and intestines.



(*A*) (*B*)

FIG. 315.—*A*, Efferent nerve; *B*, afferent nerve. (*From Brubaker's Text Book of Physiology.*)

How the Cells in the Tissues are Fed; Capillary Circulation. In certain regions of the body, in many animal forms, it is possible on account of the delicacy and transparency of the tissue to observe the flow of blood. In this relation the thin and flattened tail of a tadpole offers interesting study concerning the circulation of the blood in the smaller arteries, capillaries, and veins. After a few preliminary adjustments with the low power of the microscope, a region is often found in which the blood is flowing in both directions. Those vessels conducting blood *into* the region are *arteries;* those carrying it *away* are veins. The blood in the arteries is of a slightly lighter color than that in the

veins, while in the capillaries it seems to be quite colorless. When we view the blood streams, we may observe the *red* and *white corpuscles* floating in the blood fluid. This fluid-like substance that carries the corpuscles is called *plasma*. The blood in the arteries pulsates on account of heart-beats, while the movement in the capillaries and veins is continuously uniform. The colorless liquids in the spaces between the capillary tubes are called the lymph, and they bathe the cells of connective tissue in which the blood vessels are immeshed. Such an observation and study of the circulatory processes tells us much about the manner in which the cells of the body receive nutrition and rid themselves of wastes.

FIG. 316.—The vessels of a frog's web. *A*, Trunk of vein; and *b*, *b*, its tributaries passing across the capillary net-work. (*From Brubaker's Text Book of Physiology.*)

In the capillary circulation, as was observed above, the chief thing to remember is that the blood fluids circulate within the blood vessels, and that the outside walls of the capillary tubes are bathed in the lymph fluids. The blood in the arteries is laden with prepared foods gathered from the digestive system and the liver, and also with supplies of oxygen received in the lungs. As the blood passes through the capillary tubes, the plasma filters through the very thin walls of the capillaries and into the lymph. As the plasma diffuses through the lymph, it exchanges the dissolved nutrients and oxygen for wastes—carbon dioxide, urea, water, and heat—and then filters back into the circulatory system and is carried away in the veins. The cells of the tissues that are bathed in the lymph take up the foods and oxygen by osmosis, and during the processes of growth, repair, or secretion, release the wastes mentioned above. In order that the lymph may not become stagnant, lymph vessels

are continually conducting away certain amounts of the lymph, which are replaced by new supplies derived from materials produced from water and foods by the cells neighboring the lymph space. Thus the capillary circulation exists for but one purpose—the interchange of foods and wastes—in order that the cells may be nourished. In short, it might be well stated at this point that all the processes of the body, such as digestion, absorption, secretion, circulation, respiration, excretion, etc., have but a single purpose—the nutrition of the cells of the body.

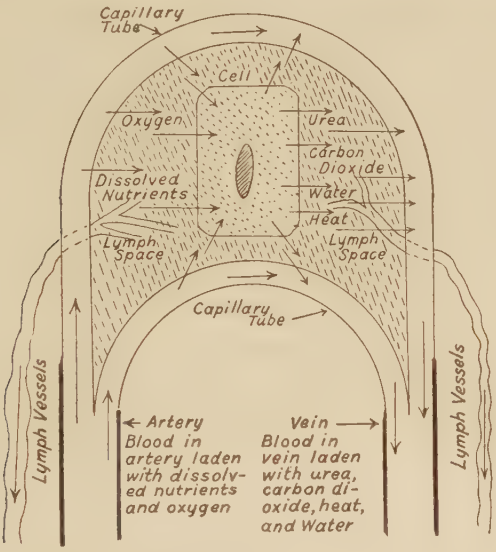


FIG. 317.—Diagram showing the exchange of materials during capillary circulation.

The Manufacturing Tissues; the Glands.—During our study of the germination of seeds and the process of growth and repair in plants much was said concerning *enzymes* or *digestive* ferments and the ability of protoplasm to build and secrete them wherever and whenever needed. Within the human body many provisions are made for the production and refinement of several kinds of secretions, of which many contain the wonderful enzymes that are so essential to all life. An organization of tissues for the purpose of preparing secretions, whether they contain the enzymes or not, is called a gland. Familiar secretions

are tears, sweat, and saliva, which are secreted by tear glands, sweat glands, and salivary glands.

Those of us who have examined the *liver* and the *pancreas* ("sweetbread" of the calf) are somewhat acquainted with the texture and general appearance of the soft and pulpy masses of tissues as they occur in glands.

When we observe a whole pancreas or liver, we see *lobe-like* divisions, and in the pancreas the lobes are again divided into smaller lobes or *lobules*. On close examination we find that the blood vessels make their exit or entrance at a given region, in the midst of which is a tube or duct which drains away the fluids that the gland manufactures.

FIG. 318.—One of the salivary glands (1) Basement membrane of the gland. (2) Duct. (3,3) The specialized cells that manufacture the saliva and its important enzyme, *ptyalin*. (4) Nuclei clear and well defined. (*From Brubaker's Text Book of Physiology.*)

The work of the gland is done by the cells that make up the lobule (Fig. 318). The preceding pages explain how the capillaries supply the cells with nutrition and remove the wastes. In the gland the delicate tissues are heavily invested by a network of capillary blood vessels, lymph-vessels, and nerves. The cells of the lobule remove the nutrients from the surrounding lymph and manufacture within their cell walls the substances for which they are peculiarly fitted. Thus the cells in the tissues of salivary glands prepare saliva, which contains a digestive ferment or enzyme called *ptyalin*. The liver, as a gland, secretes *bile*, that contains no enzyme capable of acting as a digestive ferment. The pancreas secretes pancreatic juice, which contains three very important enzymes—*trypsin*, *steapsin*, and *amylopsin*. Innumerable other glands are found in the walls of the stomach, the small intestines, the neck, and the head.

Many ductless glands exist within the body. Their secretions are discharged into the blood and thus distributed to organs and tissues wherever these are located in the body. Such glands are

known as *glands of internal secretion*. Those that pass their secretions through ducts to the surface of the body, the skin, or the mucous membranes, are known as *glands of external secretion*.

The work performed by the tissues of the several glands is the most important service rendered by any of the tissues in our body. They control every other function; they determine our state of health, our ability to do things; and, in short, the success of every act is, to a degree, dependent upon the nature of the service rendered by the glands. In this relation it must be remembered that habits of life largely determine the nature of the service that the glands of the body shall render. The tendency on the part of glands is strongly toward a high perfection of being—that is their purpose. Right living promotes this tendency, and those individuals who are aware of such forces in their bodies may do much in the way of personal habit to assist these engines of internal tendency in the right direction. Much will be said of glands as the chapter continues.

The Story of the Digestion of the Foods; the Work of Glands.—The food or alimentary canal in the human body is made up of six well defined divisions—mouth, pharynx, esophagus (gullet), stomach, small intestine, and large intestine. Of the six divisions only three—mouth, stomach, and small intestine—are provided with glands that secrete digestive ferments; hence they are the only portions capable of serving as workshops and laboratories for the preparation, digestion, and absorption of foods. Consequently the story of the digestion and absorption of foods divides itself naturally into the recital of three events—(1) digestion in the mouth, (2) digestion and absorption in the stomach, and (3) digestion and absorption in the intestine.

1. *Digestion in the Mouth.*—None of the workshops placed along the digestive tract of the human body is better contrived than is the mouth. In the front it is provided with two lips and in the back with palatal curtains. When we place food in the mouth, the palatal curtains are drawn down tight against the tongue and thus prevent foods from slipping backward and into the throat. As we chew the food, the tongue serves as a

wonderful feeding device that keeps the materials between the upper and lower teeth, the millstones of the mouth. (Fig. 319). The tongue is provided with minute "taste buds," which are scattered over its upper surface. The taste buds sample the food and by means of the sensory nerves notify the proper nerve center, which by means of motor nerves notifies the salivary glands to secrete saliva. As the saliva enters the mouth, the grinding process mixes the saliva with the food particles. The saliva contains *ptyalin*, a digestive enzyme that attacks starches and converts them to a simple and soluble sugar. As the food becomes more and more lubricated, it forms into a

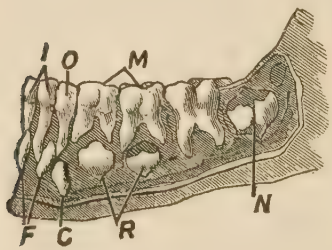


FIG. 319.—Teeth of child of six and one-half years. *I*, Incisors; *O*, canine; *M*, molars; *F*, permanent incisors; *C*, canine; *R*, bicuspids; *N*, molar. (*After Marshall.*)

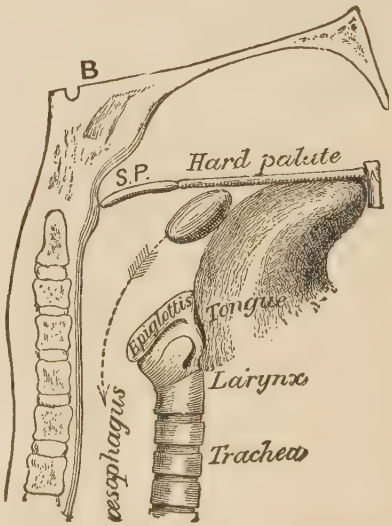


FIG. 320.—Diagram showing the position of the tongue, the soft palate, and the epiglottis during the act of swallowing the bolus of food. The palatal curtain, *SP*, is raised in order to close the passage way into the nasal cavity. The epiglottis is closed to prevent the food from entering the trachea or windpipe. (*From Brubaker's Text Book of Physiology.*)

food ball or *bolus*. When the grinding of the foods and the mixing with saliva have proceeded sufficiently, the palatal curtains are thrust aside, and the bolus is swallowed by being passed through the larynx and esophagus (gullet) and into the large end of the stomach (see Fig. 320). Thus in the first workshop the food has been pulverized and mixed with saliva, and portions of its starch (insoluble carbohydrates) have been converted into

simple sugars (soluble carbohydrates). No foods are absorbed by the tissues in the mouth.

2. *Digestion and Absorption in the Stomach.*—The stomach is simply an enlargement of the alimentary tube. The

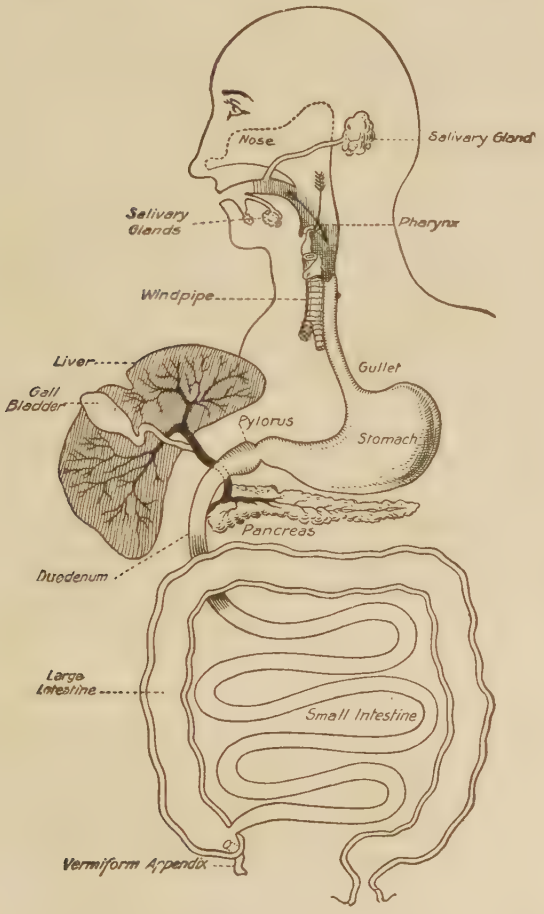


FIG. 321.—Diagram of the alimentary canal. (*From Brubaker's Text Book of Physiology.*)

large right hand portion of the stomach cavity is called the *greater pouch* and is entered by the gullet. The opposite end of the stomach cavity is called the *lesser pouch* or *pyloric portion* on account of its relation to the *pylorus*, a large ring-like muscle that regulates the escape of foods into the small

intestine. (See Fig. 321, locate stomach and observe the natural divisions as described.) Like the mouth the stomach is a combined workshop and laboratory, for not only is it able to mix and move foods, but it is provided with innumerable glands for the secretion of the *gastric* juices. To bring about a certain amount of motion, the walls of the stomach are composed of three sets of muscles which are so arranged as to encircle the stomach in three ways—longitudinally, circularly, and obliquely. The contractions of the various groups of muscles set up a peculiar wave-like motion in the walls of the pyloric end. These wave-like motions are known as *peristaltic waves*. As we shall soon see, the peristaltic waves are for the purpose of mixing and moving foods. When we begin a meal, even before food has reached the stomach, the sight, the smell, and the taste organs have sent in their communications concerning the presence of food. The motor nerves are aroused and in turn awaken the innumerable *gastric glands* in the stomach walls (Fig. 322). Large volumes of blood now enter the capillaries about the glands and discharge an abundance of required materials in the lymph spaces about the glands. The cells in the glands set to work with a vigor and manufacture large quantities of gastric juice and pour it out upon the inner surface of the stomach. As the first food balls pass into the stomach, they are conducted by peristaltic waves in the walls of the stomach to the pyloric end. In the pyloric portion the peristaltic movements are more vigorous, and as a result the food becomes mixed with a large quantity of gastric juice, which consists largely of water, a slight amount (.2%) of *hydrochloric acid*, a very important digestive ferment called *pepsin*, and a lesser one called *rennin*.

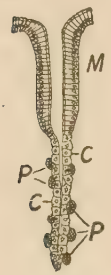


FIG. 322.—A gastric gland. *M*, Mucus-forming cells; *C*, chief cells; *P*, border cells. (*From Holmes' Elements of Animal Biology.*)

The pepsin, aided by the presence of hydrochloric acid, attacks the masticated proteins—flesh, fish, fowl, egg, and milk—and converts them into soluble proteins, which are called *peptones*. The rennin curdles the proteins in milk, after which the pepsin changes the curds to peptones. The carbohydrates—sugar

and starch—and the fats are scarcely influenced by the gastric juice.

As the food, digested and undigested, becomes more and more fluid, the pyloric muscle relaxes and allows the semi-fluids, called *chyme*, to pass into the small intestine. As the chyme passes through the pyloris, the walls of the greater pouch contract and thus force more of its store of supplies into the pyloric portion where the real work of the stomach is done. The processes as outlined continue until the stomach is emptied of its contents.

Since all foods except fats have been partly digested in the mouth or stomach, it follows that all except fats may be absorbed by the membranes lining the stomach. However, as a matter of observation, the stomach is of much less importance in absorption than was once thought. Practically, it is found that water and salts are passed quickly on toward the small intestine and are not largely absorbed in the stomach. Sugar and peptones are also found to be absorbed rather sparingly. All these substances can, undoubtedly, be absorbed by the gastric mucous membrane, but their complete absorption is prevented by their removal through the pylorus. Investigators find that pepper, mustard, and other condiments greatly hasten absorption processes on the part of the stomach.

3. *Digestion and Absorption in the Small Intestine.*—Digestion has already been defined (Chapter XXII) as the process of changing an insoluble food into a soluble one and bringing it into solution. Each of the processes thus far described is an effort directed toward bringing the foods into solution. The ptyalin of the saliva and the pepsin of the gastric juice were unable to break down the more complex and resistant particles of the carbohydrates and proteins. The fats also passed by both quite unaltered. Thus we see that the semi-fluid mass, the chyme, is still composed of many food materials that are insoluble.

The work of the small intestine is, then, to complete the work so well begun in the mouth and advanced by the stomach. In order to do this the small intestine is the best equipped laboratory in the digestive tract. In arrangement the small intestine

is twenty feet in length and only one and a quarter inches in diameter. Its muscular coat has the muscular fibers arranged in two layers, an external that runs lengthwise, and an internal that passes circularly. The mucous coat that lines the inner surface of the intestine is traversed with deep folds and tucks covered with innumerable conical elevations—the *villi*—and secreting glands of several kinds (Fig. 323). Through this tortuous canal the *chyme* is forced to make its way and receive the treatment of the strongest kinds of digestive ferments.

As shown in Fig. 321, the bile and pancreatic ducts join and enter the intestine at a point not far from the pylorus. Hence on entering the small intestine the chyme encounters three digestive fluids—the pancreatic juice, the bile, and the intestinal juice. The pancreatic juice contributes three very important ferments—*trypsin*, *steapsin*, and *amylopsin*. The trypsin, like pepsin, converts the remaining proteins to peptones; and amylopsin, like ptyalin, converts the remaining starches to soluble sugars. The steapsin attacks the fats and oils and splits them up into *glycerine* and *fatty acids*. The fatty acids are again acted upon and converted into *soaps* and *emulsions*. The bile is not, properly speaking, a digestive fluid, for it contains no enzymes capable of effecting digestive changes. While the real purpose of the bile seems to be unknown, it aids in the emulsification and absorption of fats and promotes intestinal peristalsis. The peristaltic movement in the walls of the intestine are slow, gentle, and gradual in character, but are effective in forcing the food from station to station in order that the processes of digestion and absorption may go on to completion.

FIG. 323.—Part of small intestine cut open to show folds in the intestinal lining. (*From Holmes' Elements of Animal Biology.*)

During their passage through the intestine the digested foods —those that have been brought into solution—are more or less completely absorbed by the *villi*, little organs especially fitted for the absorption of sugars, peptones, and emulsified fats. The villi are so numerous as to cause the whole inner surface of the intestine to appear velvety. The largest of the villi

TABULAR SUMMARY OF THE PROCESSES OF DIGESTION AND ABSORPTION

	Mouth	Stomach	Intestine
Digestion	Pulverizing. Mixing and softening with saliva. Glands, *salivary.* Enzymes, *ptyalin.* Carbohydrates converted to sugars. Proteins and fats unaffected.	Food storage in greater pouch. Food digestion in lesser pouch. Peristaltic waves. Glands, *gastric.* Enzymes, *pepsin.* *rennin.* Proteins converted to *peptones.* Fats and carbohydrates unaffected.	*Chyme* received from stomach. Peristaltic waves. Foods mixed with pancreatic juice, bile, and intestinal juices. Glands, *pancreas.* *liver.* *intestinal.* Enzymes, *trypsin.* *steapsin.* *amylopsin.* Proteins converted to *peptones.* Carbohydrates converted to *sugars.* Fats converted to *glycerine* and *fatty acids;* then to *soaps* and *emulsions.*
Absorption	No absorption of foods.	Possible absorption of foods digested in the mouth and the stomach, such as sugars and peptones. Salt, pepper, mustard, and other condiments stimulate absorption.	Villi. Sugars absorbed and sent to portal vein, thence to liver, and stored as *glycogen,* for immediate or for future uses. Peptones absorbed and sent by way of liver and thence into the general circulation. Fats conducted to lymphatic circulation by lymph capillaries, and thence to the base of the jugular vein and the general circulation.

are about $\frac{1}{20}$ of an inch in length and $\frac{1}{70}$ of an inch in diameter. They are covered with epithelial tissues, within which are lymph spaces, blood capillaries, and lymph vessels. As the digested foods pass the villi, the sugars, the peptones, and emul-

sified fats pass through the epithelial tissue into the lymph spaces. Here the sugar and peptones are separated from the fats. The sugars and the peptones are removed from the lymph by the blood capillaries to the portal vein, which conducts the absorbed products to the liver, where the sugars are stored away in the form of *glycogen* (Fig. 325). The emulsified fats leave the lymph space through the lymph vessel, which conducts them to the *thoracic duct.* The thoracic duct empties its contents into the blood at the base of the *jugular*

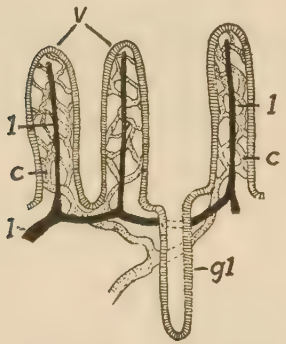


FIG. 324.—Villi, *v*, of small intestine; *c*, capillaries of blood vessels; *gl*, gland; *l*, lacteals or lymph vessels. (*From Holmes' Elements of Animal Biology.*)

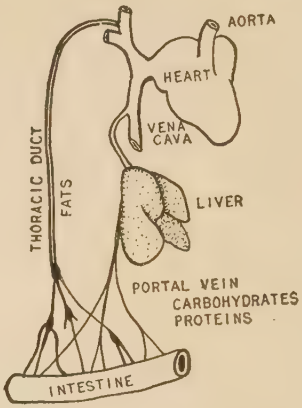


FIG. 325.—Diagram to show how the digested food gets from the intestine to the circulatory system. Note that the fats enter the blood stream directly, and that the digested carbohydrates and protein foods must pass through the capillaries of the liver before they enter the general circulation of the blood. (*From Atwood's Civic and Economic Biology.*)

vein (Fig 325), and thus the fats are distributed along with the other foods to the tissues of the body by way of the general circulation.

The Large Intestine; Its Function.—The large intestine is known as the *colon.* It is five feet long and is divided into *ascending*, *transverse*, and *descending* portions (as shown in Fig 321). Most of the substances which enter the large intestine have resisted the action of the various digestive fluids and ferments and are on their way to be discharged from the body.

The secretions of the mucous membrane that lines the large intestine furnish no digestive enzymes, and whatever changes take place are due to absorption. As the waste products accumulate, bacterial decomposition becomes very active; and thus a question of health arises from the presence of bacterial poisons which may become absorbed and be taken into the circulatory system. The function of the large intestine is to serve as a receptacle for the temporary storage for indigestible wastes and the excretions of the intestinal glands. Personal hygiene includes proper habits relative to the right functioning of the large intestine.

The Blood; the Plasma and the Corpuscles.—Examined under the microscope the blood is seen to consist of a liquid portion, the *plasma*, loaded with small bodies, the corpuscles. The plasma is a very complex fluid which consists of water (90%) and such food products as proteins, fats, sugars, and salts, gathered from the capillaries in the alimentary canal. Since the plasma is always gathering wastes from the lymph spaces, the wastes are always present in more or less abundance. Besides the foods and wastes, very small quantities of other substances received from the organs and glands are also present in the plasma.

The corpuscles are of two kinds, the red and the white, and are true cells. The red corpuscles are round biconcave discs; they do not contain a nucleus except in the very early stages of their life. They contain a very important substance called *hemoglobin*, which gives the blood its red color. Hemoglobin is a protein containing iron and has the property of combining readily with oxygen and also of releasing oxygen with equal readiness. This peculiar property of hemoglobin enables it to serve as a carrier of oxygen; for as it circulates through the air sacs of the lungs, the hemoglobin becomes laden with oxygen, which it again releases wherever needed. When the hemoglobin is laden with oxygen, it is bright red in color; and when its load is reduced, it is described as bluish. These conditions account for the difference of color in the two blood streams—the arteries and the veins. Thus the red corpuscle is specialized as a carrier of oxygen.

The white cells are often called *leucocytes* and have special labors very different from those of the red corpuscles. The leucocytes are irregular and changing in form, and indeed are very much like amœbas, which they clearly resemble in form and behavior. They are the watch dogs of the circulatory system, for they are continually on the hunt for foreign material and bacteria, which they engulf and devour. The leucocytes are able to pass through capillary walls and search the lymph spaces and even the tissues for bacteria. They congregate in regions of injury and bacterial infection, where their one mission is ever the same—to restrict the opportunities and activities of disease-producing bacteria.

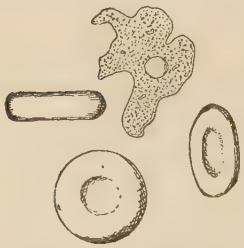


FIG. 326.—Red and white blood corpuscles. The white corpuscle has an appearance very much like that of the amœba. (*From Atwood's Civic and Economic Biology.*)

When the blood is withdrawn from the body, it has the curious property of forming a solid, jelly-like substance, the *clot.* The clot is composed of a substance called *fibrin* derived from a soluble substance called *fibrinogen.* Exposure to air causes the blood to clot, and the process may be greatly hastened by the addition of fine powders or by beating with a stick. The clotting of blood performs a very important service in the way of checking the bleeding of wounds, which would otherwise be difficult to control even in the instance of very slight wounds.

The Need of a Circulatory System; the Arteries and Blood Pressure.—Thus far throughout the course much has been said concerning protoplasm, food supplies, digestion and assimilation of foods, secretion of enzymes, waste products, and their manifold relation one with another. In cities and towns we saw the necessity of two separate water systems leading into each and every home. One system conducted pure water to the home, and the other conducted away the wastes—the sewage. No matter whether the person who lived in the home was a banker, a lawyer, a clerk, or of any other occupation, he required the convenience of the two systems of water. It is precisely the same in the human body. No matter whether a cell is found in the muscular tissues of the

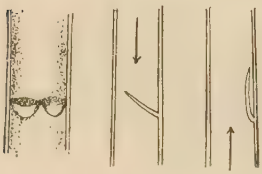
arm, or the nervous tissues of the brain, or the tissues composing the eye, or other places, the capillaries that lead into the lymph space in which the cell lies must bring in fresh supplies of nutrients and carry away the manufactured products and wastes.

In order that the above conditions may be accomplished, we find the animal body most wonderfully equipped with a pulsating heart that maintains a constant flow of blood in a closed system of arteries, capillaries, and veins (as shown in Fig. 327). Since the same blood stream is continuously flowing through the same set of tubes hour after hour, it would become greatly clogged and stagnated with the foul wastes received from the lymph spaces, if provisions were not made for constantly renewing its purity and regulating the presence of other more or less desirable materials. Hence in the general scheme of blood circulation we find the blood circulating (1) through the capillaries of the intestines, in which stores of food are received; (2) through the liver, which regulates the presence and quantities of sugar in the circulating blood; (3) through the lungs, in which carbon dioxide is removed and oxygen restored; (4) through the kidneys, in which the blood is cleansed of every kind of waste and discharged in the form of urea.

FIG. 327.—Diagram of the circulation. (1) Heart. (2) Lungs. (3) Head and upper extremities. (4) Spleen. (5) Intestines. (6) Kidney. (7) Lower extremities. (8) Liver. *After Dalton.*)

As indicated in the diagram (Fig. 327), the heart is the muscular

engine-pump that maintains a constant stream of blood flowing through the arteries, the capillaries, and the veins, from birth until death. The muscles that make up its walls compose the engine, which contains within itself all the equipment of a pumping device, in fact not one pumping device but two. Each pump consists of two cavities—an *auricle* and a *ventricle*—in which a provision of valves determines the direction in which the blood must flow. The pump on the right hand side is concerned with the pumping of *venous* blood from the two large veins, *superior* (from above) *and inferior* (from below) *vena cava*, and forcing it through the *pulmonary artery* that conducts all venous blood into the lungs. In Chapter XI it is told how the blood on passing through the capillaries of the air sacs of the lungs gives up carbon dioxide, water, and heat, and receives oxygen in return. After being so purified the blood passes through the pulmonary vein to the left pump and is consequently forced out into the *aorta*, a large artery that divides into lesser arteries which conduct a large portion of the blood to the head and the remainder to the various portions of the body and its extremities.



A *B* *C*

FIG. 328.—Valves in vein. *A*, Valves as they appear when vein is cut open; *B*, section of vein to show closing of valve to prevent backward flow of blood; *C*, section showing position of valve when blood is flowing normally. (*From Holmes' Elements of Animal Biology.*)

Since the blood meets a good deal of resistance in passing through the capillaries, the heart is able to drive the blood into the arteries more rapidly than it can be at once discharged. The walls of the arteries are somewhat elastic, and as a consequence they are somewhat stretched after each heart beat. Before the next heart beat occurs, the contracting walls of the arteries force their excess supplies through the capillaries. In this way the *elastic effect* in the walls of the arteries aids in maintaining a constant flow of blood through the capillaries. Furthermore the elastic walls of the arteries maintain everywhere a constant pressure which results in an even flow of blood in all the capillaries along the arterial route. Thus the capillaries located at a distance from the heart receive their blood supplies as well as those situated near it.

The veins, on the other hand, are less elastic than the arteries; they are, indeed, more like mere tubes through which the blood flows back to the heart. The veins are never over filled, for the reason that the heart is always drawing on their supply, and consequently no considerable blood pressure can ever occur in the veins. Hence there is a difference of pressure in the two reservoirs—arteries and veins. It is this difference in pressure that forces the blood through the organs. During work or exercise or other activity the veins are subjected to momentary pressures brought about by the contraction of the muscles among which the veins pass. Such pressures often tend to force the blood backward. Such a reversing of the blood would give rise to serious consequences, and to prevent such a condition from ever taking place the veins are provided with pocket valves that permit the blood to flow in but one direction.

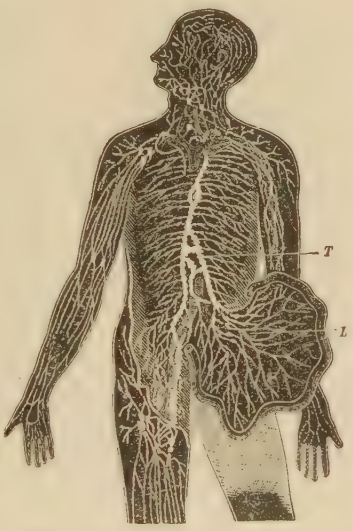


FIG. 329.—Lymphatic system. *L*, Lacteals; *T*, thoracic duct. (*From Holmes' Elements of Animal Biology.*)

The Lymph and the Lymphatic System.—In connection with the circulatory system it should always be remembered that the cells of the tissues are bathed in lymph and never with blood. While the red corpuscle never occurs in the lymph, the white corpuscle abounds in great numbers. Since the lymph is constantly being replenished by fluids which diffuse from the blood while passing through the capillaries and from the tissues that surround the lymph spaces, it shows considerable difference of composition in the different organs. The chief function of the lymph and lymph vessels is the absorption and the transfer of materials into the blood system. The lymph vessels that are so abundantly supplied to the intestines for the purpose of absorbing emulsified fats and conducting them to the *thoracic duct*, are given the special name *lacteals* on account of the

milky appearance (lac, milk) of the lymph in the region of the intestine.

In close relationship to the lymph vessels are the lymph glands. They are centers in which leucocytes arise. Infections often travel along the courses of lymph vessels and cause swellings in the neighborhood of the lymph glands and in the glands themselves. The tonsils are chiefly composed of lymphatic tissue and for this reason are very apt to become infected. The bacterial poisons arising from infected tonsils are quickly spread from these organs throughout the body and thus produce very ill effects. To prevent such infections from arising the tonsils are often removed.

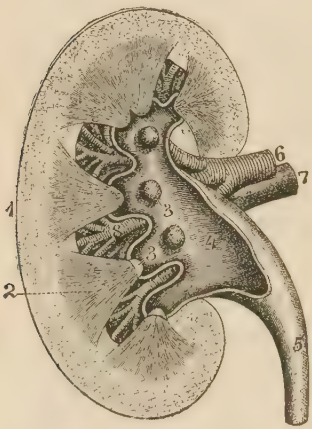


FIG. 330.—Vertical section through kidney. (2) Pyramid showing the renal tubules opening at (3) the papillæ; (4) cavity of kidney; (5) ureter; (6) renal artery; (7) renal vein; (8) branches of the renal arteries and veins. (*After Leidy.*)

The Kidneys and the Cleansing of the Blood; Excretion.—The process of getting rid of waste materials is known as *excretion*, which in the animal body is effected mainly by the *kidneys*, *skin*, *lungs*, and *large intestine*. The wastes leave the body in the form of gases, liquids, or solids. The lungs are organs that are specially fitted for the excretion of carbon dioxide gas and water vapor; the large intestine, the solid wastes and excretions of the alimentary canal; the kidneys and the skin, the soluble wastes, especially water, salts, and urea.

The kidneys are the most important organs for the cleansing of the blood, from which they separate certain waste matters in a suitable form for removal from the body. They are shaped like a bean and are about four or five inches long and one and one-half inches wide. The kidneys are located on each side of the spinal column just below and behind the stomach, and are the only stationary organs in the abdomen. Each kidney receives a large artery from the aorta (renal

artery) and gives off a large vein (renal vein) that joins the inferior vena cava. Passing from each kidney is a duct called the *ureter*. The ureter of each kidney passes downward and connects with the *bladder*, which serves as a storage for the fluids secreted by the kidney.

The kidney is a gland composed of a mass of minute tubes, called *tubules*, lined with epithelial cells which perform the real work of the organ. As the blood courses through the minute tubules, considerable quantities of water, various salts, and urea are discharged into the cavity of the kidney. Once in the cavity of the kidney, these poisonous wastes drain through the ureter and into the bladder.

The most important function of the kidney is the elimination of urea, a compound of nitrogen, that results from the breaking down of proteins during the process of tissue building. When disease of the kidneys impairs their activities, this poisonous waste accumulates in the body and death is the result. A well known disease of the kidneys is Bright's disease, which is one of the most fatal of human ills. Alcohol is one of the most potent of all the causes of kidney diseases, because of the fact that so much blood is passed through these organs that the secretory cells are especially exposed to the action of this drug. Excessive beer drinkers are prone to diseases of the kidneys, which are due not so much to the alcohol that they consume as to the strain imposed upon these organs when laboring to remove the excessive amounts of fluids added to the blood. Good drinking water taken in sufficient quantities is very beneficial to the proper functioning of the kidneys. The presence of proper quantities of water avoids the concentration of the wastes which are ruinous to the delicate structures of the kidneys.

In connection with the kidneys it might be added that the liver is an important organ of excretion, not on account of the bile which it discharges into the intestine, but for the large amounts of urea that it releases while building up substances out of proteins. The urea is, of course, thrown into the blood, from which it is removed by the kidneys.

The Skin and Its Fourfold Labors.—While the most of us consider the coat of skin that everywhere envelops our bodies

a means of protecting the more delicate and sensitive organs that lie beneath, the skin performs other services that are quite essential to our health and welfare. For we shall find that it serves as a device for regulating the temperature of our bodies, as an organ of excretion, and as a sensory surface well suited to the reception of many kinds of impressions from the outside world.

In structure the skin is composed of two layers—the outer called the *epidermis* or *cuticle*, and an inner and a deeper one known as the *dermis* or *cutis* (Fig. 331). The outer cells of the epidermis are dead and are continually being rubbed off and replaced by cells from beneath. The epidermis as a layer is particularly noticeable when it is raised from the dermis during the formation of a blister. The under part of the epidermis contains a brown pigment which in colored races is abundant, and which in white people is increased when they become tanned or freckled. (See *SM*, Fig. 331.) The dermis is much thicker than the epidermis and consists of connective tissue containing muscle fibers, the tactile organs of the nerves, blood vessels, sweat glands, fat tissues, and many other structures.

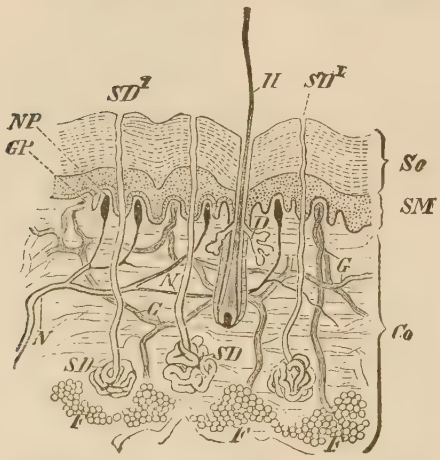


FIG. 331.—Section of skin of man. *Co*, dermis; *Se* and *Sm*, the epidermis; *D*, oil gland; *F*, fat; *G* and *GP*, blood vessels; *H*, hair; *N*, nerve; *NP*, nerve papilla, or tactile organs; *SD*, *SD'*, sweat-gland and duct. (*From Holmes' Elements of Animal Biology.*)

As an excretory organ the skin is provided with sweat glands which take the form of coiled tubes whose ducts open through fine pores at the surface of the body. In the palms of the hand these openings are plainly observed with the aid of a good hand lens, and it is estimated that about 2,000,000 of these glands occur over the entire body. Wherever hair occurs, the *sebaceous* or oil gland is also present. There are usually two oil glands

for each hair follicle, and their secretions keep the hair and the surface of the skin more or less oily. When a hair falls out or is pulled out, another hair may grow again provided that the little papilla at the bottom of the hair follicle is not injured. However when the scalp is poorly nourished, the hair falls out and is not replaced. As a consequence the person becomes bald and may resort to hair tonics, which are, of course, useless. For it must be remembered that all growth is the result of cell activities—changes in protoplasm. External applications of tonics do not effect protoplasmic conditions of growth and repair.

As an organ for regulating the temperature of the body the skin is unexcelled. So remarkable is the regulation of heat that the temperature of the body during health never varies more than the fraction of a degree during the extremes of summer and winter. The temperature of the body is maintained by burning carbohydrates, proteins, and fats in the cells of the tissues, but the skin regulates the rapidity with which the heat is allowed to escape, and the temperature of the body remains constantly the same. When the blood is too warm, either from exercise or from climatic conditions, there is an enlargement of the blood vessels of the skin. As the blood travels near the surface when flowing through the capillaries in the skin, it radiates considerable heat into the space about the body. At the same time the sweat glands secrete considerable quantities of perspiration, which evaporates on the surface of the body. Now it has already been shown that evaporation is a cooling process. Consequently, as the water in the perspiration evaporates, great quantities of heat are taken up from the skin and underlying blood vessels. When the nerves of the skin are stimulated by cold, they send impulses to the blood vessels supplying the skin and thus cause them to contract and handle less blood. Hence the blood is driven from the skin to the more internal organs. The deeper the blood circulates the less heat is lost by radiation, the less perspiration is discharged, and consequently the less cooling results from evaporation. And thus nature has devised a wonderful self-regulating device for the maintenance of a constant temperature within our bodies.

The skin is the place in which at least three kinds of sensations —touch, cold, and warmth—find their origin. These sensations are quite distinct from one another, as is shown by the observation that on certain parts of the skin some of them may be felt, but not others. This condition of affairs indicates that each sensation—touch, cold, or warmth—has its own set of *end organs* and *nerve fibers* terminating in the skin. The sensory or afferent nerves of cold or warmth not only carry to the brain the impulses of cold or warmth, but also serve as important means of bringing about such *reflex* action as will aid in the regulation of heat production and heat output.

From what has been said it can be readily understood how necessary it is to keep the skin clean. The skin becomes clogged with dirt from the outside and wastes from the inside. As the wastes accumulate in the pores of the skin, some of them undergo decomposition, which gives rise to disagreeable odors. Clogged skin pores hamper the regulation of temperature, and are directly the cause of a low state of personal efficiency. Proper habits of bathing not only free the skin of a burden of foul materials, but keep the skin and incidentally the whole body in a high state of perfection. Cold showers for moderately robust persons tone up the blood vessels of the skin and render them much less liable to colds and various other forms of infection. After each cold bath, a vigorous rubbing should be applied to the whole surface of the skin in order to bring about a strong circulation in the blood vessels near the surface. The exhilarating glow of the skin resulting from the rubbing serves as a tonic to the skin and to the whole body.

Sensations; Nervous System; Reflex Action.—From day to day we are continually talking about things which we have seen, or heard, or tasted, or smelled, or touched. That is, we are relating experiences which we have received through such special sense organs as the eye, the ear, the tongue, the nose, and the touch organs of the skin. The experiences which we relate are the result of *impulses* received by the way of the eye, the ear, or other sense organs. In this relation we know that the eye is coupled with the brain by means of a nerve—the *optic* nerve. If the optic nerve be cut, blindness is the

result; even though light does fall on the eye and is brought to a focus on the retina (Chapter XVIII), impulses go no farther than the cut and therefore excite no sensation of light in the brain. No matter, then, how wonderfully constructed an eye or an ear may be, we already know that it is quite useless unless it is properly connected with the brain by means of a nerve. In short, it is in the brain that *impulses of light* are translated as *sensations of light.* The eye is a wonderful device by means of which light can send impulses through the optic nerve to the brain. The ear is a wonderful device by means of which sound impulses are received by the auditory nerve and thus by the brain. The touch organs or tactile organs on the ends of the nerves that lie imbedded in the skin send impulses of heat, or cold, or pain, by means of nerve fibers to the brain, where such impulses are translated, are interpreted, as *sensations* of warmth, or cold, or pain. *Sensations are brain translations of impulses.* But in everyday life we are in the habit of saying "the eye sees," or "the ear hears," or "the finger feels," etc. We refer the sensation to the organ that brings about the sensation, and by so speaking we forget that it is the brain which is thus active.

FIG. 332.—The cerebro-spinal nervous system. (*From Holmes' Elements of Animal Biology.*)

In the above instances we refer the sensation to the external object which causes it. When the skin is touched with a piece of ice, we do not say that the skin is cold, but that the ice is cold. When the eye receives a green light, we do not say that the retina is green, but that the object which reflects the light

is green. When we feel the surface of a solid, we refer the smoothness or roughness to the object examined. However, when we pierce the finger with a needle or pound it with a hammer, we refer the resulting pain to the injured finger and not to the needle or hammer. Again, when we have gone without food or drink for some hours, we feel hungry, or we feel thirsty. Hunger, thirst, and pain from injuries are all sensations arising from impulses sent over the nerve routes to the brain. In short, the brain is the seat of sensation—the center of consciousness. In order that impulses may be transmitted to the brain and thus come into consciousness, the body is everywhere in communication with the brain. The means of communication is effected by means of a well organized nervous system which consists of a *brain*, a *spinal cord*, *nerve trunk lines*, *nerve centers*, and *nerve cells with their fibers*. The great majority of the nerve trunks take their origin from the brain and the spinal cord which together form the great *cerebro-spinal nervous system* (Fig. 332).

Earlier in the chapter it was pointed out that the nerve cell is specially suited to the task of bearing messages. In this connection it must be constantly borne in mind that every nerve fiber—axone—is a part of a nerve cell, and that whenever a nerve fiber is broken away from the body of its nerve cell, the fiber dies. No matter how far the minute and thread-like axone reaches out to distant muscles, glands, blood vessels, etc., the whole portion of the nerve fiber receives its nourishment from the cell body of the nerve (see Fig. 315). Now when we examine the structures that compose the brain and the spinal cord, we find them made up of two kinds of nervous tissues, which are commonly known as *gray matter* and *white matter*. The gray matter is made up largely of the nerve cells and their branching processes, while the white matter is composed of the nerve fibers with few or no cells. While the nerve cells are found only in the brain, in the spinal cord, and in the nerve centers called *ganglia*, the nerve fibers extend to every part and portion of the body. Thus it is the nerve fibers that bring in the impulses of cold, or warmth, or pain, or taste, or odor, or light, or sound, and it is also

other nerve fibers that carry orders from the brain, or spinal cord, or ganglia, to the muscles, the glands, the blood vessels, and other organs. Since all the impulses are borne into the brain and the spinal cord, and since all the messages that excite these organs to action come from the brain and spinal cord, or nerve centers commanded by those organs, the brain and spinal cord together constitute what is known as the *central nervous system.* Those nerve fibers that carry to the central nervous system the impulses of odor, taste, sound, pain, hunger, etc., are known as *sensory* (or *afferent*) nerves, while those that carry the messages from the central nervous system to the muscles, the blood vessels, and the glands are called *motor* (or *efferent*) nerves. Since all the nerve fibers, sensory and motor, meet in the central nervous system, the impulses received by a nerve cell may be communicated to other nerve cells and finally transmitted to remote parts of the body.

We are already acquainted with the fact that many portions of our body *act* only when we *will* the act to take place. Such acts are described as *voluntary acts.* Many portions of our body perform their labors independent of any action whatsoever on the part of the will. Such acts are known as *involuntary acts.* The movement of the arms, legs, jaws, and similar organs are under *voluntary control.* The actions of the heart, the stomach, and the intestines are absolutely beyond voluntary control, and therefore such acts are known as *involuntary acts.* In order to accommodate the two sets of acts the *cerebro-spinal* or the *central nervous system* takes charge of the voluntary acts, while the *sympathetic nervous system* governs and controls all the involuntary acts. Thus we are prepared to find in the nerve centers of the body a wonderful plan for providing *nerve force* that stimulates the activities of widely differing organs, and at the same time brings them into harmonious action.

The brain and the spinal column are very intimately associated; indeed, so closely associated are the two great organs that they may be considered as extensions of one another. Yet they have distinct labors to perform, and of the two organs the brain is the master organ and the spinal cord the assistant organ. The brain is the seat of *consciousness;* that is, the brain

is concerned with mental processes that have to do with our ideas, emotions, volitions, feelings, memory, imagination, and perception. The spinal cord is concerned with none of these processes. In what manner then does the spinal cord aid and assist the brain? What are its duties, and how does it perform them?

At first many of the acts of life, such as walking, are more or less voluntary. That is, every step is the result of an activity

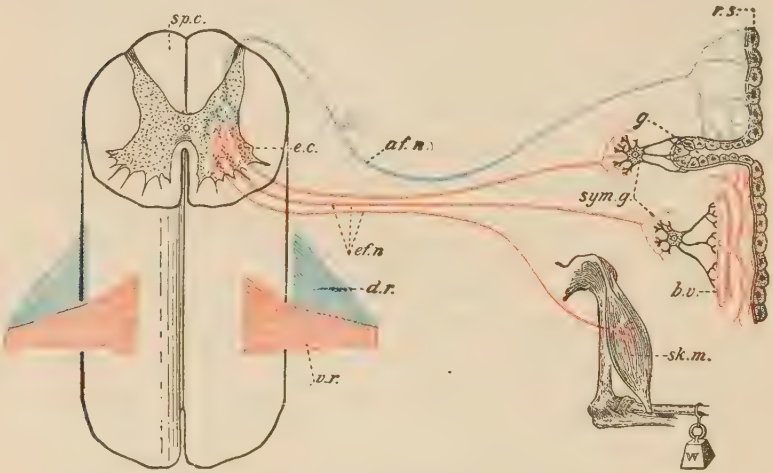


FIG. 333.—Diagram showing the structures involved in the production of reflex actions. *r.s.*, Receptive surface such as skin, mucous membrane, sense organ, etc.; *af.n.*, afferent or sensory nerve bearing impulse to motor cell, *e.c.*, in the anterior horn of the gray matter of the spinal cord, *sp.c.* *ef.n.*, efferent nerves, or motor nerves bearing motor impulses to responsive organs, directly to the skeletal muscles, *sk.m.*, and indirectly through sympathetic ganglia, *sym.g.* to blood vessels, *b.v.*, and to glands, *g.* Thus the work of muscles, glands, blood vessels, and every responsive organ of every kind is under the control of an organized nervous system. (*From Brubaker's Text Book of Physiology. After G. Bachman.*)

that is directed by the brain. As we become more and more skillful, the act becomes less and less a conscious act. This condition of affairs comes about gradually. The attention of the brain to each and every step is more and more withdrawn, and our ability to walk seems to become more or less automatic. Such a result is due to the fact that the act of walking is given over to a definite group of nerve cells located in the spinal column. As time passes, the group of nerve cells to which *walking* has been assigned become more accustomed and more

skilled in directing and controlling all the processes concerned with the art of walking. Finally, as an act, walking is performed quite independently of any attention on the part of the brain.

Acts which may be performed without thinking about them are *reflex;* also those acts which are performed independently of the will although with full consciousness are *reflex*. Likewise every act in which we become skilled, such as playing the piano, swimming, skating, writing, and many of the acts involved in driving the automobile, are at first voluntary acts resulting from a great deal of direction coming from the brain. But as the nerve centers to which each of these acts is assigned become more and more educated, the nerve centers become quite independent of the brain, and thus voluntary acts become reflex acts. We can check or prevent many of our reflexes by means of impulses sent down from the brain, but many reflexes are performed even when the upper part of the spinal cord is injured so that the lower part of the body is no longer under voluntary control—brain control. A person who would have to give his attention to every adjustment of his legs while running or walking, who would have to think about the working of the eyelid, and a thousand and one other bodily movements, would be so handicapped that the accomplishment of the ends of life would be impossible. Thus we are able to realize the wonderful provision wherein the spinal cord by means of reflexes is able to perform the menial services of life and thus leave our brain—our mind—free for the pursuit of higher things.

Habits and Mental Hygiene.—Out of the first aimless movements of the head, eyes, arms, and legs of the infant comes coördination of action such as balancing, walking, running, and the more complicated motions acquired in play and work. As the trained nerve centers become more skilled and coördinated for the performance of their labors, the consciousness has no more need to trouble about the matter. When the unconscious parts of the nervous system have been trained to do certain things under certain conditions, we say a *habit* has been formed. Habits are the result of the tendency of the nervous system to go on doing what it has been trained to do. Since

the tendencies are capable of being directed, there is a reason for endeavoring to form good habits and to avoid bad habits of every kind. The nervous system is concerned not only with our physical habits but also with our mental habits, which demand exactly the same treatment. Correct habits of pronunciation, of spelling, of style in writing, of observation, and of reasoning demand the same care and attention as habits of good manners at the table, or of dressing, or of bicycling. In either case it is important to acquire our physical and mental habits in definite forms and never to let them go by chance. For a person who is to develop any habit of action or behavior is served worst if a weak indulgence allows him occasional slips and exceptions. It is much easier and more worthy to learn precise habits than loose ones.

The brain, like the muscles, is improved and strengthened by exercise and injured by overwork or idleness. A man may especially develop one set of his intellectual faculties and leave the others to lie undeveloped until he almost loses or actually loses the power of using them at all. The intensity of the battle of life tends to produce a one-sided mental development. The business man is so concerned with competitive business methods that he loses the intellectual enjoyment of art, literature, and science. The literary man is incapable of sympathy with the business and scientific worlds, while the scientific man has often no appreciation of the achievements in the fields of literature and art. A good education in early life on a broad basis of literature, history, mathematics, and natural science is the best security against a one-sided mental growth.

"Every person has in the course of his life many trials and tribulations. He is the possessor of uncomfortable feelings, secret thoughts, ardent desires, and internal mental conflicts. From time to time the average normal individual brings these affairs into clear consciousness and disposes of them. Worries and anxieties are brought from dark corners of the mind, are carefully considered and placed where they belong. Other means of getting rid of one's troubles is to forget them, to banish them to the land of nothingness. Interest in others and in

other things lessens the importance of any trial or conflict, no matter how serious it may seem at first. The mental unfortunate is often unable to throw off his troubles. His secret desires or thoughts get the better of him; he is unable to put them aside; in many cases he does not know how to put them aside. His ability to balance and equalize mental events is not sufficiently powerful, and finally, perhaps, after a long warfare, his ideas and secret longings burst forth in the shape of false beliefs—delusions—or he imagines that he hears voices or that he sees strange things—hallucinations. Thus he becomes insane." (Mullan.)

Mental upsets are caused by poisons made within the patient's own body as the result of infectious disease of various kinds, by improper or ill-digested food, by poor environment or by a lack of sufficient sleep that is so essential to the best care of the nervous system. Fear, magnified anxiety, over excitement, and despondency are the arch enemies to a well-ordered life. Probably no condition is so important in keeping the nervous system in a healthy state as enjoyment of work and cheerfulness in daily life. Plays and games which give the keenest enjoyment, especially those involving physical activity, are of the utmost importance for the well-being of this master tissue of the body. Hence in order to be hygienic one must be mentally hygienic; that is, one must think well, feel well, and practice well that which he has learned. The efficiency of the nation depends upon the efficiency of the individual units of which it is composed. The efficiency of an individual is in direct proportion to the quality and health of his brain and nervous system.

Projects

1. To make a study of some of the common causes of headache and of sleeplessness and to outline a course of action for the avoidance of these disorders.

2. To investigate the common causes that give rise to disturbances of the digestive tract and to prescribe a course of action that will lead to the prevention of these disorders.

3. To learn to know what a *sprain* is, and the proper course of procedure and treatment for it.

4. To outline a course of action and treatment for giving "first aid" for burns and scalds.

5. To learn how to distinguish between *heat stroke* and *heat prostration* in order to be able to know what treatment should be given in each case.

6. To learn what to do for a person with nose bleed.

7. To learn the cause, symptoms, and treatment for a person suffering from shock; fainting; and convulsions.

8. To learn what should be done when a foreign body has entered the eye; the ear.

9. To learn the cause of styes on the eye and to outline a course of treatment for them.

10. To make a study of the dangers that may arise from slight wounds and to outline a course of action for guarding against these dangers.

11. To make an inquiry into some of the permanent injuries to the body arising from the presence of decayed teeth.

12. To make an inquiry into the relationship of diseased or enlarged tonsils and adenoids to general health conditions.

13. To learn to know what is meant by the term *physical defect*, to identify some common physical defects, and to outline corrective and preventive habits of life for those that may be acquired or intensified by wrong habits of life.

14. To discover what is meant by the terms "defenses of the body," "health and resistance," "factors that lower the resistance," "preventive medicine," and "degenerative diseases."

15. To make a study of the life and work of Florence Nightingale and to report the nature and character of the service that this wonderful personality rendered in the interests of humanity

16. To learn what is meant by first aid, and the relationship of a first aider to the doctor.

17. To write a theme in which it is demonstrated that a knowledge of first aid principles has a tendency toward the prevention of accidents.

18. To demonstrate the method of applying roller bandages to the finger; to the thumb; to the arm; to the toe; to the ankle and lower leg.

19. To learn the uses of splints and to demonstrate one use that may be made of splints.

20. To learn what a tourniquet is and how it is used in the avoidance of danger to life.

21. To learn what is meant by an emetic, and the use of two or more good ones.

22. To learn what to do when bitten by a dog. (Report includes Pasteur treatment and means of securing such treatment.)

23. To learn how to rescue a person from a live wire and how to treat him after he has been rescued.

24. To write a theme on the dangers of self-medication.

25. To write a theme on the dangers arising from the use of patent medicines or narcotics and drugs.

26. To select a project concerned with right habits of personal hygiene and to set it forth in terms of health and personal efficiency.

CHAPTER XXVII

FOODS AND AN INTELLIGENTLY SELECTED DIET

Object.—To learn how the various kinds of foods serve the various needs of the body, in order to know how to select them intelligently.

Foods Serve as Fuel and Materials for Growth and Repair.—A few years ago the manager of a sawmill in one of the northern states had contracted to supply several manufacturers of wood materials with twenty carloads of lumber per day. Arrangements had been completed for the cutting and the handling of the logs and for shipping out the manufactured lumber. The mill had been overhauled, the saws sharpened, the boilers tested, and the engines put into readiness. Competent workmen, skilled engineers, and expert foremen were on hand and ready to take their places. However, there was one difficulty. The manager, being unable to obtain the high grade of coal for which he had contracted earlier in the year, accepted a very low grade of coal that consisted of slack and much shale. The engineers did the best they could with the low grade of fuel, but found that in spite of their best efforts they could not get enough steam to supply the engines which drove the saws. Consequently the mill ran behind on its contracts. The low grade of fuel possessed insufficient stores of energy for the development of the power required by the saws.

While it seems easy enough to understand the nature of the difficulty in the instance of the sawmill, there is another case in which people do not seem to see the effects arising from poor fuels. Students of social science have found that from one-fifth to one-third of the people of our great cities live at or below the poverty line. Consequently the children in such homes seldom receive sufficient quantities of good grades of foods. In the more unfortunate homes the breakfast of the child may consist of a piece of bread and a cup of coffee. Such an

amount of food is insufficient, and, furthermore, it is not of the right kind. It would be much better if such a child could have butter on the bread and a glass of whole milk in the place of the cup of coffee. The bread, the butter, and the whole milk would supply the child's body with that which it needs to keep it warm, to build up worn out tissues, and to stimulate growth and proper development. Without the fat added to the bread and the whole milk in the place of the coffee the child is like the sawmill without sufficient power.

Not only are the children of poor families improperly nourished, but often whole families of better circumstances get into difficulties with their foods. Especially is this true of the children of families in which the children are notional about the things which they eat and select foods on the basis of false or acquired tastes. Bad habits regarding food selections are dangerous to the individual who forms them, for, sooner or later, he finds himself suffering not only from an impaired digestive system but from a body troubled with many ills. Sometimes whole nations get into difficulties with their foods, as for instance the people of some of the Oriental nations in which the inhabitants subsist exclusively on a diet of rice. In the case of the Oriental peoples who live on the one-sided rice diet, we find them suffering greatly from a disease known as *beri-beri*. During periods of great food shortages in Japan and portions of China we find the people suffering from an eye disease which is greatly relieved when the people are given a diet of fish oils. From what has been said it is quite clear that no one of the class foods—carbohydrates, proteins, or fats—is sufficient for the maintenance of our bodies. In an earlier chapter we learned that protoplasm consists of carbon, hydrogen, oxygen, and nitrogen. Since fats and carbohydrates consist only of carbon, hydrogen, and oxygen, no amount of starch and fat could prevent a man from dying of starvation, because his body requires some food which contains nitrogen.

Again, man has changed his habits of living so completely during the past century and a half that we find the nature of the foods which he uses now very different from those used by his immediate forefathers. The question arises: Can the

human body adapt itself to changes and endure? Our more primitive ancestors had to be content with such natural foods as milk, eggs, whole grains, fruits, leafy vegetables, and the flesh of game of every kind. These natural foods provided a proper quality and a right proportion of carbohydrates, protein, and fat. These foods contained also a proper amount of indigestible substances or wastes, which kept the small and large intestine in a proper state of action and thus prevented many of our civilized ills that arise from constipation.

The foods which satisfied our more primitive forefathers are not so acceptable to our present way of living. Our meats, grains, fruits, and oils are preserved, or purified, or polished, or pickled, or canned. Some we extract or distill for the purpose of obtaining highly concentrated foods more agreeable to our tastes. The animal products we dry or freeze and then store away. The grains we mill to flour or polish off the husks. In short, we are constantly applying the principles of our ever advancing civilization to the refinement of the foods we eat and the fluids we drink. Often the process of refinement is carried too far, and the *live foods* that nature has so well constructed are converted by civilized methods into *dead fuels*. When foods are robbed of some of their vital products, they fail to serve our bodies to the fulness that nature had intended. In order that we may live well and be efficient members in the society in which we live and work, it is necessary that we know how to live. In order that we may do this with some degree of certainty the theme of this chapter is given to foods and the nature of the service that they render to the body.

FOOD TESTS

Object.—To learn how to test for the presence of the various kinds of foods.

(Recall or repeat the experimental studies relative to food testing in Chapter XXI.)

MILK TESTS (HOME PREPARATION)

Object.—To make an examination of a sample of milk for the purpose of determining the presence of impurities.

APPARATUS.—Funnel. Quart bottle.

MATERIALS.—Pint bottle of milk. Cotton.

PROCEDURE.—1. Place a plug of cotton in the upper end of the stem of a funnel, and place the funnel in the top of the quart bottle. Pour a pint bottle of milk into the upper part of the funnel and allow it to filter through the cotton plug. When the milk has filtered through, remove the plug carefully and examine it for the presence of dirt, hair, particles of hay, and other foreign matter.

2. Can you account for the presence of dirt and foreign materials in milk? Do you believe it to be the result of carelessness, and to whom is it due? Is the presence of such foreign material indicative of unclean milk? Are disease-producing bacteria more likely to be in clean or unclean milk? Give reasons for your answer.

3. How is clean milk to be secured? Is there any reason why a producer should labor and contrive to supply the market with clean milk and only with clean milk?

4. What diseases are carried and thus distributed by contaminated milk? Name all possible sources of bacterial contamination. Is bacterial contamination of milk preventable? Explain.

5. Does the city government make any provision for safe guarding its inhabitants against the distribution of contaminated milk? Explain. Of what importance is clean milk to a city and why should a city government be concerned with the nature of the dairy products that are sold and distributed to its dwellers?

6. Is the city concerned with the inspection of dairy products only or of all food products, such as eggs, meat, vegetables, etc.?

7. What department of the city government is concerned with food inspections? To whom do they report their findings? Who enforces the "food laws" in the city? What can the citizens do in the way of coöperating with the department that seeks to secure pure foods?

8. Report your findings and conclusions to the above in the form of a theme. Select an appropriate title.

THE BABCOCK TEST (DEMONSTRATION)

Object.—To determine the per cent of fat in milk by means of a Babcock milk tester.

APPARATUS.—A Babcock centrifuge machine. Two Babcock milk bottles. A pipette marked 17.6 cc. A graduate marked 17.5 cc. Means for keeping a small pan of water hot.

MATERIALS.—Pint bottle of milk. Sulphuric acid, density 1.83.

PROCEDURE.—1. Remove the cap from a pint bottle of milk and stir thoroughly in order that a uniform sample may be obtained.

2. Using the pipette transfer exactly 17.6 cc. of milk to each bottle.

3. Using the graduate add to each bottle exactly 17.5 cc. sulphuric acid. The sulphuric acid is added to the milk to dissolve all the solids except the fat, which will afterwards rise to the top when separated by means of the centrifugal machine.

4. Thoroughly mix the acid and the milk in each bottle by means of a rotary motion and thus avoid getting curds into the neck. When the work is properly done, the mixture is dark brown in color and very hot.

5. Place the bottles in buckets located on opposite sides of the machine and centrifuge for five minutes (800 revolutions per minute or more).

6. Set the bottles in a pan of hot water and add sufficient hot water to bring the fat *just* to the neck of the bottle.

7. Centrifuge for two minutes.

8. Add just enough hot water to bring the column of fat opposite the graduated scale that is etched on the neck of the bottle.

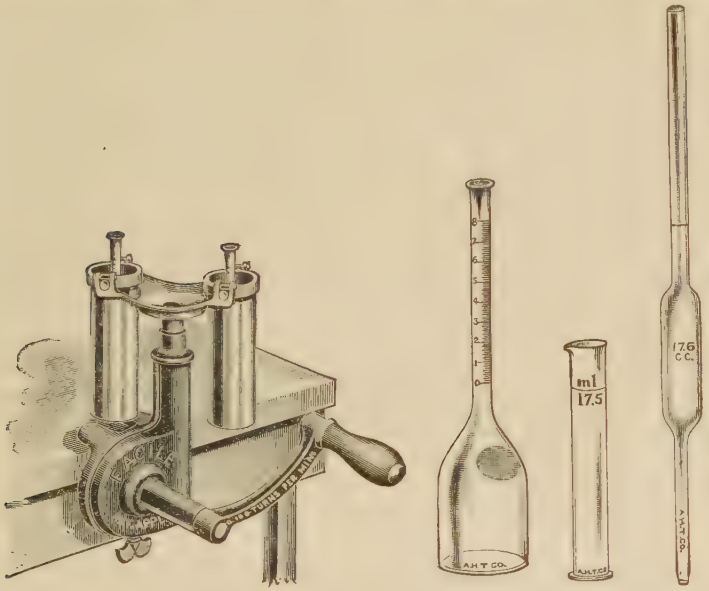


FIG. 334.—A Babcock centrifuge machine, a Babcock milk bottle, a graduate, and a pipette.

9. Centrifuge for one minute.

10. The per cent of fat obtained may be read directly from the scale, which is graduated in tenths of 1%. The fat in milk varies from 2.2 per cent to 9.0 per cent. The United States standard is 3.25 per cent. What standard does your state require?

11. Of what value is such a test? Should a dairy farmer use it? Explain. Do creameries use it? Milk stations? Why are two samples always tested at the same time?

MILK ADULTERANTS (DEMONSTRATION BY STUDENTS)

Object.—To make a study of the effects brought about by the presence of adulterants in milk.

APPARATUS.—Three or more bottles.

MATERIALS.—Pint bottle of fresh milk. One per cent solution of formaldehyde. Borax. Bicarbonate soda.

PROCEDURE.—1. Pour one-fourth of a pint of milk in each of three bottles labeled *A*, *B*, and *C*.

2. Add several drops of 1% solution of formaldehyde to bottle *A*, several drops of saturated solution of borax or boric acid to bottle *B*, and allow *C* to remain unadulterated. Cover the bottles with a cap of wetted paper.

3. Set the bottles aside and observe daily.

4. In which of the bottles does the milk first decompose and give off odors? Which seems to remain "good" for the greatest length of time? Can you see any reason why producers are tempted to place these adulterants in their milk before hauling and shipping it to market?

5. Which of the adulterants serves as the best preservative? Are these preservatives used in the place of ice and cleanliness? When milk fails to sour, is it indicative of the presence of a preservative?

6. Formaldehyde (sometimes called formalin) is one of the most poisonous preservatives found in foods. The use of formaldehyde as a food preservative cannot be too strongly condemned. The food chemist is able to employ very sensitive chemical tests which will show the presence of these chemicals whenever they are present in milk and other foods. Does the city employ a skilled food chemist? Obtain a report of this department and read pertinent parts to the class.

7. Other forms of adulteration are common. The addition of water is the oldest method. Skimming off portions of the top cream is another. The addition of coloring matter, such as carmel, annatto, and dyes, to give the appearance of richness in cream, is frequent. Any and all of the above adulterants are dishonest and fraudulent and are added with the intent to rob and deceive.

8. Whence do the funds come that pay the wages and other expenses of the health department? Are you in favor of raising money by taxation in order to support this department? Explain. Is the inspection of foods a part of the work of the health department? Name other services rendered by this department.

The Human Machine and Its Need of Food.—As was pointed out in the introduction to this chapter, the body needs a constant supply of food substance. In the service of the body a food may supply one or more of the following needs: (1) as a supply of power to the muscles in order that they may perform work, (2) as fuels for supplying heat with which to keep the body warm, and (3) as building materials for growth and repair, or as cell materials for the manufacture of secretions and enzymes

that are so essential to bodily welfare. The fats, sugars, and starches serve as power and fuel foods. While the proteins serve as power foods, their chief service is that of serving as building materials to the tissues.

FOODS AND THEIR USES

Carbohydrates	Fats	Proteins
1. Produce energy. 2. Are converted into fats. 3. May be stored away in the liver as glycogen.	1. Produce energy. 2. Are converted into bodily fats.	1. Produce energy. 2. May give rise to fat in the body. 3. Build up living tissues.

The Fuel and Power Foods.—The fuel and power foods consist of the fats and substances already defined as carbohydrates. Both plants and animals provide us with our fats and oils, of which the most common are butter, suet, tallow, lard, olive oil, cottonseed oil, and other vegetable oils. The chief carbohydrates are sugar and starch, which are wholly supplied by the green plants. It is impossible to maintain the body properly on the fuel and power foods alone, because they do not supply the necessary elements which are essential to the growth and repair of the several kinds of tissues. The experiment of feeding animals exclusively on a fuel diet has often been tried, but the results are always disastrous to well being and to the life of the animal. The result is always the same—the animal starves for want of proteins—nitrogenous substances—and consequently the victim dies from wasted tissues.

Fats and Economy in Their Uses.—Fats are concentrated fuel foods and for this reason are important in the diet of laboring people who are engaged in manual labors. But they also have another value. It has been found in countries where the fat ration has been cut very low that the reduction of these materials interferes with the normal growth of children and with the healing of wounds of every kind. Some of the fats of animals contain minute quantities of substances (*called*

vitamins) which are necessary for the growth of new tissue or the repair of old. Butter, milk, and yolk of egg are particularly rich in these substances. Suet, oleomargarine, and other fats derived from animals contain minute quantities of these vital substances, but it seems that vegetable fats and oils do not. Since growth is dependent upon the presence of these vital substances, animal fats must be included in the diet of growing children. Hence the diet of children should consist of sufficient quantities of whole milk and butter or oleomargarine made of beef fat.

In order to conserve the animal fats for table use, the vegetable oils and hardened fats should be used for cooking purposes for two reasons. (1) If the output of butter is reduced, more whole milk will find its way upon the market and thus be available to a larger number of children who are not now receiving adequate supplies of this wonderful food. (2) Vegetable fats and oils can be produced more economically than animal fats.

Not only are fats essential in a diet, but they are desirable for the richness of flavor that they impart to foods which are thus made more palatable. However, as a nation we are using and wasting from two to three times as much of the fats as we have actual need for. We can, and we should, reduce our consumption of rich pastries and cakes, omit many of our fried foods, and use all trimmed fats for cooking or turn them back onto the market for the manufacture of soap, oils, and other similar essentials. By doing these things as a nation we shall be able to lessen shortages in these valuable substances so necessary to our life in the way of foods.

Carbohydrates; Sugar and Starch; Glycogen.—When we think of the vast quantities of wheat and similar cereals that are yearly harvested and manufactured into food stuffs, we are unable to comprehend the huge quantities of starchy foods that find their way to our tables. Of course, coupled with this gigantic quantity of carbohydrates are the potato and vegetable harvests of every kind. In 1915 the world's crop of sugar was 2,000,000 tons, and this country used more than one-fifth of the whole crop. At present the American people are using on the average 85 pounds of sugar per year or about seven pounds

per month. This is more than twice the average amount for France or Germany and several times that of other European countries. Since the time of the Civil War our average use of sugar has been steadily increasing about a pound a year. Sugar now comprises about 5.5% of the average American diet.

Sugar is more easily absorbed and transformed into heat energy than any other food that enters the body. A small lump of sugar can be used by the body to produce as much heat as an ounce of baked potato. Because sugar can be digested and absorbed more readily than starch, it is useful in times of exhausting labors.

Pure sugar is especially agreeable to the taste and is a highly concentrated food, and for this reason there is danger that we may eat more of it than we need. Therefore people are being constantly warned not to eat too much candy or sugar. We eat potatoes when we have an appetite and are hungry, but we eat candy when we have it regardless of whether we are hungry or not. Of course this means the wasting of food and the lowering of the efficiency of our bodies as well as the bringing on of indigestion and other ills. We can satisfy our craving for sugar and sweets by using such foods as honey, molasses, maple and corn syrups, dates, figs, raisins, jellies, jams, and preserves.

It was stated in Chapter XXVI that the carbohydrates are transformed to sugars during the processes of digestion. The sugars are gathered by the portal vein, which carries them to the liver, in which the sugars are transformed and stored away as *glycogen*. Glycogen is a true carbohydrate and for this reason is often known as *animal starch*. The amount of fats present in the blood is the greatest during or immediately after the digestion of a meal. However, in the case of sugar the amount seldom, if ever, varies from about 0.05 of an ounce to a quart of blood plasma. This nice regulation of the presence of sugar in the blood is brought about by the liver, which stands at the gateway of the circulation and pays out its stores of sugar to the blood. Provision is thus made for the storage of fuel foods and for the maintenance of bodily heat and power in time of need. Yet it should never be forgotten that food

must be disposed of in some way whenever it is taken into the body. If the supply at any time is more than is needed, the body can use a part of it advantageously by storing it away for future use. While it is good for the body to have a certain amount of surplus stores, excess quantities above that which can be stored are imperfectly used and poisonous products accumulate and injure the body.

The Proteins, the Tissue Builders of the Body.—As was already intimated, the proteins are substances composed of the same elements as is the protoplasm that makes up the living materials of our bodies. If we again compare our body with a steam engine, the proteins are the substances that furnish the steel and the iron of which the engine is built. As the engine operates, the steel and the iron wear and waste away. Ultimately the worn and weakened parts must be replaced, otherwise the engine becomes useless. In the body the process of wear and waste is constantly accompanied by replacement. The materials for replacement are extracted from the proteins and from them only. A portion of the proteins serve also as fuel foods.

Our bodies consist of about two-thirds water and more than one-sixth protein materials. Hence a person who weighs 150 pounds has in his body 100 pounds or about 12 gallons of water and approximately 27 pounds of protein substances. The proteins may be derived from plant and animal sources. Beans and peas contain a great deal of protein; wheat and corn have some protein values; while oatmeal has a little more than either. These foods are all fairly good sources of protein foods, especially when eaten in large quantities. Lean meat of any kind, fish, eggs, milk, cheese, beans (except string beans), and peas contain a great deal of protein. A pound of medium fat beef-round contains about three ounces of protein. An egg contains about a quarter of an ounce of protein; a glass of milk, one-fifth of an ounce; a pound loaf of white bread, about one and a half ounces of protein. And, as stated before, carbohydrates, fats, or oils contain no protein.

Many experts and investigators have given much study to the question of how much protein a person needs every day.

It is everywhere agreed that a grown man needs at least two ounces and most authorities increase or even double this amount. Furthermore, it is also agreed that a growing child should select at least one-third of his proteins from animal foods. Milk and eggs are much better for the child than is meat.

Meats and Economy in Their Uses.—The world's meat supply is being rapidly depleted. As a nation we are producing less meat in proportion to our population each year. This is because of the decrease in land available for grazing and the resulting increase in the cost of raising live stock. There is great need, then, for economy in the use of meats, especially beef, veal, lamb, and pork, which are the most easily shipped. Meats are valuable in our diet for two reasons, (1) the fine flavor which they impart to our foods, and (2) their proteins which are so necessary to the building of blood, muscles, bones, and other parts of the body. In order to make the best possible use of the meat flavors, meats may be used in combinations with cereals, potatoes, and other vegetables in stews, soups, and pies. In this way a little meat can be made to go a long way and serve us quite as efficiently as when we use larger quantities in a less economical manner.

The proteins that we need can easily be supplied wholly or in part by other foods, such as fish, eggs, milk, cheese, dried beans and peas, and nuts, which contain a large proportion of protein. Three-fourths of a pint of milk, or two small eggs, or a one and a half inch cube of American cheese, or three tablespoonfuls of cottage cheese furnish, each, about the same amount of protein as a medium serving (two ounces) of meat. Although much cheaper, the proteins of vegetable origin are not so good in quality as those of milk, eggs, meat, and fish. But when vegetable proteins are prepared or supplemented with milk proteins, the vegetable foods may supply a large part of the protein in the diet.

Milk and Its Importance as a Food; Cheaper Than Meat.—As a food milk is more important than meat. Like meat it contains protein and fat, but it is much richer in mineral salts, especially lime salts, which are so essential to the formation of bones. Milk contains the vital substances (vitamins) more

abundantly than most foods that contain these stimulating ingredients. Although exceedingly minute quantities are present in any food that contains them, these substances are now recognized as of great importance in bringing about proper conditions of nutrition.

Meat is a more expensive source of protein foods than is milk. This is true not only for the consumer who buys the meat at a high price per pound, but for the country as a nation. As pointed out in Chapter XXIV thirty six bushels of corn provide enough food energy to supply 1025 men for one day. But when the same corn is fed to cattle and changed to beef, it provides only enough food energy to supply 45 men for one day. Thus the animal is not an efficient machine for turning plant proteins into meat protein. However, in the case of milk the return is several times larger. One-third to one-half the protein eaten by the animal is obtained as milk protein.

All of these facts emphasize the importance of encouraging the production of milk. Children need it especially. Even at fifteen cents per quart it is relatively inexpensive as a source of valuable fats, proteins, lime salts, and the life-stimulating vitamins. It is one of the first duties of the government of every city to make possible the reception and distribution of sufficient quantities of a high grade milk. The success of its child population depends upon the availability of supplies of whole milk. Many cities have organized the dairy communities in their neighborhood with the purpose of improving the quality and quantity of milk products. Such efforts are always of mutual benefit to the dairy farmer and the inhabitant of the city.

Wheat; Gluten and Its Relation to the Art of Making Bread.—There are two kinds of bread which we are accustomed to use, breads raised by means of yeast and the so-called quick breads. The latter variety is usually leavened with baking powder or soda and an acid such as sour milk. In both kinds it is possible to use meals, or flours made from corn, oats, rye, barley, buckwheat, or potato flour. In yeast bread not more than one-fifth to one-third of other cereals or potato flour can be substituted for wheat flour. This is because wheat flour alone

contains the gluten necessary for making a light and porous loaf. Gluten is the protein of wheat. It can be separated easily by making a stiff dough of ordinary flour and a little water and washing this ball of dough until all the starch is removed. The elastic mass that remains can be stretched without breaking. When flour, water, and yeast are mixed together and kept at about ordinary room temperature, the yeast ferments and produces bubbles of carbon dioxide gas. The gluten in the flour stretches as the bubbles of carbon dioxide gas grow larger or more numerous. As the process continues, the dough is gradually changed to a mass of thin-walled cells. When the bread is baked, the gas expands and stretches the gluten still more. In this way a light, porous loaf is produced.

No other grain contains exactly the same kind of protein, although in rye there is a gluten somewhat similar to that in wheat. That is why yeast bread can be made entirely from rye flour. A lighter loaf is obtained when some wheat flour is also used. It is because of the exceptional quality of the gluten in wheat that wheat bread has come so largely into use. Wherever the civilized world sits down to dinner, bread is more often present than any other of the food substances. From ancient times bread has been regarded as the staff of life.

The Mineral Salts.—A third class of foods which is required by the body, though in small quantities, is the mineral salts. There are about seven pounds of mineral salts of all kinds in a body weighing about 150 pounds. A large part of this salt is of the same type as that which we use as table salt. Iron is one of the mineral substances needed in the body. While the amount of iron in the body is hardly sufficient to make a small finger ring, it is one of the most important elements in the body. It is necessary in the building of the red corpuscles in the blood. Whenever iron is lacking the blood can not do its work, and the person so troubled is suffering from a disease known as anæmia.

Most of the salts which are needed by the body are widely distributed throughout nature, and hence they come to us in almost all kinds of foods. However, in pure sugar and pure

oils there are no salts. Three of the most important salts that are essential to the welfare of the body are the salts of calcium, iron, and phosphorus. It is of the highest importance that one's diet shall be so selected as to provide for these important elements. Milk, eggs, and meat are good sources of all three—calcium, iron, and phosphorus—except that milk does not contain sufficient iron, and meat contains not enough calcium. When legumes and cereals are used whole—that is, with their bran—they are good sources of all three elements.

Vitamins, the Vital Substances.—Much has already been intimated concerning the presence of very small amounts of *vital substances* that are found in certain foods which we eat. In 1897 a Dutch physiologist by the name of Eijkman made a study in nutrition by feeding some pigeons a diet of polished or milled rice and water. Polished or milled rice is that which has the hulls completely removed and is in every way like that which we usually buy at the grocer's. As a result of the diet of polished rice the pigeons soon began to suffer from a nervous disorder which caused them to stagger as they walked. Finally the pigeons were unable to stand up and shortly after died. In 1908 medical officers serving in the United States army stationed in the Philippines found that the natives who lived chiefly on a diet of milled rice were suffering from a disease known as beri-beri. When the sufferers of this disease were fed with the hulls and polishings from the milled rice, they recovered and were soon cured of the disease.

In 1912–1913 Dr. Casimir Funk of Poland repeated the work of Doctor Eijkman, and he observed the same effects among his pigeons when they were fed a diet of polished rice and water. But when he fed them an extract of the hulls taken from the rice, the pigeons soon recovered from their nervous disorders, were again able to walk uprightly, and were apparently well. From the extracts of rice polishings he was able to obtain a very small quantity of crystalline substance which he called *vitamin*, (Latin *Vita*=life, English *amine*=pertaining to nitrogen compounds derived from ammonia). While this name is not satisfactory to the general public, it is quite probable that it will remain. As a result of the above discoveries, other

investigators and students went to work on the various other foods that make up our everyday diet. As a result of their labors it was found that in many ways our civilized methods of preparing commercial food stuffs were robbing the foods of this vital substance, vitamin, which in some manner is necessary to the proper functioning of our bodies. While vitamins are substances of unknown composition, their presence in our foods is essential to health, and their absence would mean death.

If all the food which we use in everyday diets contained the vitamins, no attention to the selection of foods for the purpose of securing the vital substances would be necessary. However, as already pointed out in the course of this chapter, whole milk, whole wheat bread, and animal fats contain the vitamins, while white bread, lean of meat, and sugar do not contain them. In this relation it might be well to know that three vitamins have been discovered, and that they have been named vitamin A, vitamin B, and vitamin C. Each of the three vitamins has a distinct labor to perform when once it has entered our bodies. Vitamin A, a fat vitamin, is necessary to the growth of our bodies. Vitamin B is essential to the burning of the foods and their transference into the tissues. Vitamin C is necessary if anæmia and general weariness of mind and body are to be avoided.

Vitamin A occurs in butter, milk, cream, beef fat, yolks of eggs, spinach, lettuce, carrots, sweet potatoes, wheat, rye, and barley. Codliver oil is very rich in this vitamin. While vitamin A is soluble in fats and oils, vitamin B is soluble only in water. Orange juice and yeast are especially rich in vitamin B, which also occurs in the outer layers of cereals, in milk, meat, eggs, fruits, and above mentioned vegetables. Vitamin C is found in fresh vegetables and abundantly in oranges, grape-fruit, lemons, tomatoes, and raw cabbage. Boys and girls who are "finicky" about what they eat and select sweets and pastries in the place of creamed toast, creamed potatoes, and similar food enriched with dairy products, and who demand always white bread in place of whole wheat bread, suffer sooner or later from a general lassitude of mind and a weariness of body that makes them generally inefficient.

It has been found that vitamins are sometimes destroyed in the preparation of food. For example, it is necessary to pasteurize milk in order to free it from dangerous bacteria, but the process of pasteurization may partially destroy some of the vitamins. If pasteurized milk is to be used, it is often necessary to supplement the milk with orange juice, prunes or prune juice, or other foods which supply the vitamins.

Foods in Terms of Fuel Values.—In Chapter IV we considered means and methods for the measurement of temperature and heat. At that time a British Thermal Unit was found to be the amount of heat stored away in a pound of water when its temperature was raised one degree Fahrenheit. In dealing with the heat values of foods the *calorie* is used in the place of the British Thermal Unit. A calorie is the amount of heat stored away in a kilogram of water when its temperature is raised one degree Centigrade. This is about the same as raising one pound of water four degrees Fahrenheit.

Investigators have found that 9.3 calories of heat are released when 1 gram of fat is burned in a specially designed piece of apparatus called a *calorimeter*. Other foods have been tested in like manner and the following results obtained.

1 gram of dried carbohydrate yields 4.1 calories
1 gram of dried protein yields 4.1 calories
1 gram of dried fat yields 9.3 calories

These results are known as the *fuel values* of carbohydrates, proteins, and fats. However, it must not be thought that because these yields are obtained by scientific methods in the laboratory they are the same as when burned in the muscles of our bodies. While all the three foods may serve as fuel to the body, some seem to do this better than others. For this reason fats and carbohydrates have been termed the fuel foods. The proteins have been termed the tissue-building foods for the reason that they provide the nitrogenous materials that are not present in the others. Furthermore it has been found that a person requires about 14 calories per pound of body weight. That is, a person who weighs 100 pounds must devour foods that will provide his body with 1400 calories, while one who

weighs 150 pounds requires an amount of food that will yield 2100 calories.

APPROXIMATE COMPOSITION OF FOODSTUFFS[1]

Food Materials (edible parts)	Water, per cent	Protein, per cent	Fat, per cent	Carbohydrate, per cent	Ash, per cent	Heat value of one pound (in calories)
Apples	83.2	0.4	0.5	14.2	0.3	285
Bananas	75.3	1.3	0.6	22.0	0.8	447
Beans, dry	12.6	22.5	1.8	59.6	3.1	1565
Beef, sirloin	60.0	18.9	18.5	....	1.0	1099
Beef, round	68.2	21.3	7.9	....	1.2	709
Beets, cooked	88.6	2.3	0.1	7.4	1.6	180
Butter	10.5	1.0	85.0	1.0	0.3	3491
Cabbage	91.5	1.6	0.3	5.6	1.0	143
Celery	94.5	1.1	0.1	3.3	1.0	84
Cheese, cream	30.2	25.9	33.7	2.4	4.2	1890
Cherries	80.9	1.0	0.8	16.7	0.6	354
Chicken	72.7	21.5	2.5	....	1.3	493
Cornmeal	15.0	9.2	1.9	75.4	1.4	1620
Eggs	73.8	13.4	10.5	....	1.0	672
Lettuce	94.7	1.2	0.3	2.9	0.9	87
Macaroni	10.3	13.4	0.9	74.1	1.3	1625
Milk	87.0	3.3	4.0	5.0	0.7	314
Oatmeal	7.6	16.1	7.2	67.5	2.0	1811
Onions	88.0	1.6	0.3	9.9	...	220
Oranges	87.1	0.8	0.2	11.6	...	233
Oysters	87.1	6.2	1.2	3.7	2.0	228
Peanuts	9.0	25.8	38.6	24.4	2.0	2490
Pork, shoulder	50.3	17.3	31.1	....	0.9	1585
Pork, salt	12.1	0.9	82.8	....	4.2	3555
Potatoes	78.9	2.2	0.1	18.4	1.0	378
Rice	12.4	8.0	0.3	79.0	0.4	1591
Strawberries	90.0	1.0	0.6	7.4	...	169
String beans	89.0	2.3	0.3	7.4	...	184
Sugar	2.0	....	....	97.8	0.3	1815
Tomatoes, fresh	95.3	0.9	0.4	3.9	0.3	104
Wheat, flour	12.5	10.8	1.1	74.8	0.5	1608
Wheat, graham	13.1	13.3	2.2	71.4	1.8	1628

[1] From "Brownell's General Science and the Economics of Daily Life." P. Blakiston's Son & Co., Philadelphia.

However, the chief factor which determines the number of fuel units required by the body is the amount of muscular effort that is put forward by the muscles. Men at hard labor,

such as the digging of ditches or the shoveling of coal, require from 20 to 25 calories per pound weight of the body. During sleep it has been found that the body requires about 10 calories per pound weight of the body. Bodies not protected from exposure to cold by proper clothing require more food fuels than do those properly clothed. The usual diet which we find in three hearty meals a day has sufficient fuel to more than meet the needs of the body. In the majority of instances we consume one and one-half times as much as the body needs. This is due to the fact that portions of the food leave the body undigested, part is destroyed in the digestive tract, especially in the large intestine, and a part is dissipated in the body, with the result that the excess of heat above that required is given off by the skin.

Diet; Complete and Economical.—Quite enough has been said to convince one that it is necessary to use care and intelligence in selecting the foods that make up our every day diet. We are never satisfied with the organization of a factory or mill unless the work is done in such a way as to produce the largest possible results with the fuel consumed. We are, on the other hand, very often careless about our bodies. For instance, we sometimes put into our bodies more food than is necessary. We enjoy the taste of what we are eating and go on overloading the body furnace beyond its needs and sometimes even beyond its natural capacity. In this relation it should never be forgotten that food must be disposed of in some way whenever it is taken into the body. Excessive quantities are always a source of trouble in that they give rise to poisonous substances which work injury to the human machine. (1) Proper quantities, (2) good qualities, and (3) right proportions of each of the classes of foods are the three essentials of a successful diet.

There is still another factor which must not be overlooked. Food materials have to be selected by people under our modern way of living with due regard to the cost. Some food substances are very cheap, and there is a tendency to use them to the exclusion of other foods which would be better for the body. The poor white people in many sections of the South live on corn bread, molasses, and salt pork. These foods are cheap and

A Classification of the Foods for the Purpose of Making the Proper Selection and Maintenance of a Balanced Diet That is Best Suited to Our Daily Needs

Fruits and vegetables Select these for essential salts, vitamins, and materials that prevent constipation		Carbohydrates and fats Select these as fuel foods. Some contain proteins and some vitamins			Proteins Select these for building and repairing the tissues. Some contain fat and vitamins
Fruits	Vegetables	Starch	Sugar	Fats	Dairy products, meats, nuts, and fish
Choice for breakfast					
Apples Apricots Berries Cantaloupe Currants Grapes Grapefruit Oranges Peaches Pears Prunes Rhubarb		Biscuit Bread Cereal Muffins Potatoes Toast Waffles	Honey Syrup Sugar	Bacon Butter Cream Margarine (from beef)	Eggs Fish Meat (sparingly at this meal) Milk, whole
Choice for lunch					
See list above. Fruit salads Water melon	Asparagus Beets Celery Greens Parsnips Radishes Spinach Squash String beans Tomatoes Turnips Salads: Cabbage Celery Lettuce	Biscuit Bread Brown Graham Corncake Croutons Macaroni Muffins Noodles Potatoes Rice Shortcake Wafers: Oatmeal Graham	Sugar in: Cakes Jams Jellies Preserves Syrups	Bacon Butter Cream	Cheese Eggs Fish Fish: Chowder Salads Milk Milk: Custards, junkets, etc. Nuts Nut: Butter Salads
Choice for dinner					
See list above. Bananas Dates Figs Raisins	See list above. Vegetable: Soups Salads	Bread Graham Rye White Crackers Potatoes Rolls	Sugar in: Cakes Desserts Ice cream Ices Jams Jellies Pies Preserves Puddings	Butter Cream Gravies Oils in salads	Beans Cheese Clams Crabs Fish Meats Meat substitutes Milk Nut loaf Oysters Shrimps

Choice for a day — Age 12–18

Breakfast:
- Fruit
- Cereal
- Milk
- Toast
- Butter

Lunch:
- Hot roast beef sandwich
- Cocoa
- Bread
- Butter
- Baked apple

Dinner:
- Meat and potatoes
- Green vegetables, cooked
- Fresh fruit or salad
- Bread and butter
- Ice cream
- Milk

falsely gratify the tastes of these people, but such foods make up a very incomplete diet. In many city families the situation is not greatly different. Their foods consist of baker's bread, cakes and pastries, lard, fat meats, syrups, and cheap candies. In both of these cases the diet would be much improved by the addition of milk, or eggs, or fresh meats, in order to supply animal proteins and the essential vitamins. Furthermore they should have fruits and vegetables to supply mineral salts and more vitamins. Oatmeal and other cereals which are not too highly milled or polished, and whole-wheat breads would be also very helpful.

When buying foods and thinking of their cost, people ought to know that a good grade of whole milk is essential in a child's diet, and that it forms a very desirable portion in the diet of a grown person. Many of the cheaper cuts of meats are a good source of protein. Shoulder and neck and parts of the flank of beef and the heart, and soup meats in general are quite as rich in proteins as the higher-priced cuts. The vegetable vitamins and required salts, which are the cheapest, are usually found in apples, bananas, and the winter vegetables, such as raw cabbage, carrots, turnips, squash, and parsnips. Green vegetables and fresh fruits when in season are especially desirable.

The diet of a growing child requires more animal fat than does that of an adult, which may consist of larger amounts of the vegetable oils and fats. And as previously stated the diet of the young and the growing youth must always consist of sufficient amounts of whole milk, butter, whole wheat breads, and eggs. If such facts are known and acted upon when we are purchasing and using foods, it is quite possible to have a complete and wholesome diet at no greater cost than that of some of the incomplete diets which are now so common.

Projects

1. To make out a menu for each meal for a week for the purpose of securing a balanced diet.

2. To make a trip to a milk station for the purpose of observing the means and methods that are employed in the handling of milk. Report sanitary meas-

ures that insure the purity of milk. Why are there different grades of milk? What is the purpose of grading milk?

3. To make a visit to a large bakery in order to observe the various processes and devices that are employed in the art of bread making. Report all processes from flour and yeasts to the wrapped loaf.

4. To learn how to can a vegetable by the cold-pack method.

5. To make a visit to the health department in order to make inquiry concerning the work of food inspection and to observe the nature of the work that is being done by the food inspecting squad.

Suggestion.—Make an appointment. Report your actual observations. Do you consider the services of the department essential to the welfare of the city? Explain.

6. To learn how to pasteurize milk for the purpose of pasteurizing the home supplies

7. To make a visit to the kitchen of a large hotel for the purpose of observing the methods and devices employed for cleaning and sterilizing dishes and utensils; of cleaning and preparing foods, etc.

8. To learn the first principles of sanitation and to put them in practice in the home.

(*a*) Cleaning the refrigerator.

(*b*) Cleaning garbage and ash cans and providing them with suitable covers and placings.

(*c*) Screening of windows and doors and the repairing of screens and screen doors.

(*d*) Ridding the premises of flies, roaches, and other pests.

(*e*) Cleaning and freeing the yard of accumulated wastes, and planting grass in bare and unused places.

9. To learn how to select and buy foods in order to do the food purchasing for the home.

10. To learn how (select one)

(*a*) to make bread,

(*b*) to broil a steak,

(*c*) to cook a cereal,

(*d*) to make "Johnny cake,"

(*e*) (selection).

11. To compare the amounts of protein that can be purchased for 25 cents in the form of milk, of meat, and of bread.

12. To make a study of the food canning industry and to determine the importance of such an industry to our modern way of living.

13. To learn why thickly populated countries are more concerned with the raising of cereal and vegetable foods than they are with the production of meats.

14. To learn the relation of cold storage and cold storage cars to our food supply and our modern way of living.

15. To make a study of the sources of sugar and the art of extracting and refining it.

16. To make a study of the history of sugar refining and its relation to our modern way of living.

Suggestion.—What did people use for sweets before the art of refining sugar came into use? Is sugar a food or a mere luxury?

17. To make a study of the source of fish and game foods and to determine the causes and conditions that allow fish foods to continue in existence and outlast the game foods.

18. To learn to know the difference between whole wheat flour and ordinary wheat flour, polished and unpolished rice, and the value of these substances as foods.

19. To learn to know what is meant by the following terms: diet, balanced diet, mixed diet, complete diet, and prescribed diet.

SECTION III

IMPROVING THE CONDITIONS OF HUMAN LIFE AND GROWTH

The Individual and the Community.—Throughout the course our attention has been directed to the study of the forces and materials in nature and their relationship to living organisms. The forces and materials have been defined as environmental factors, the chief of which are heat, light, air, water, and food constituents. The living organisms were found to be manifestations of that most wonderful of all substances—the substance of protoplasm. In the drop of pond water under the microscope we saw minute forms of living organisms swarming from place to place. Under the higher power of the microscope we observed a small mass of clear slime changing its shape, throwing out projections of its structureless substance, and creeping from one part of the drop of water to another. We recognized that the slime was living, and we gave it a name—amœba.

While the amœba represents the lowest form of life, man represents the highest form of life. While there are animal forms that possess greater muscular strength and endurance, no animal form possesses the capacity for nervous organization equivalent to that found in man. Animals are governed largely by their natural instincts, while man is directed by the creative powers of his own mind and intellect. While the lower forms of animal life are dependent upon their environment, man seeks to regulate to a greater or less degree many of the factors that oppose him. To this end he fashions wood and stone into homes in which he creates an environment suitable to his desires. When stone quarries and forests are wanting, he mixes the clays and sands, and manufactures a suitable building material. He domesticates the plant and animal for purposes of food and clothing. He sees the wind, the streams, the

waterfalls, and the fuels of the earth as sources of energy which he immediately harnesses to machines for the performance of work. This and much more man is doing to make his life more certain and more successful.

While the human individual is a highly organized creature capable of the performance of the many duties that are concerned with his own welfare, he seldom lives independently of other human individuals. Indeed, men have found through long generations of slow and painful experience that they are able to increase their powers and to utilize them to better advantage when organized into community groups. By an *organized community* we mean *a group of people who live in the same place under the same laws and regulations and have a common interest.* Wherever a community exists, community problems arise. These problems are concerned with all kinds of service necessary to the welfare of the community. Problems concerned with supplies of wholesome water, sanitation, food inspection, clean air, protection against infectious diseases, and many others are essentially community problems.

Yet the solution of a community problem depends upon the common interest of the many individuals of the community. If the individual citizens are not interested in wholesome drinking water, it is not likely that the community will be provided with good water. A clean city is very likely to be a relatively healthful community. But city cleanliness consists of cleanliness in the home and home premises, cleanliness of shop and factory, and cleanliness of alleys and streets in the neighborhood of home, shop, and factory. In short the success of any community is dependent upon the degree of coöperation of individual and community. Individuals who are not acquainted with the importance of wholesome water, pure air, and sanitation are apt to hinder and oppose many community undertakings so necessary to the welfare and happiness of the community. In order to quicken our public spirit, to stimulate a stronger desire for coöperation, and to bring about a feeling of greater responsibility, the subject matter of this unit of our science work is concerned with community problems and their relation to human welfare.

CHAPTER XXVIII

WHAT THE INDIVIDUAL MUST DO TO IMPROVE

Object.—To make a study of the conditions that have to do with human life and growth in order that proper care may be given to and right uses be made of the human mechanism.

Individual Efficiency.—Some one has aptly said that the mind and the body constitute a partnership. In this connection it was Locke who wrote: "A sound mind in a sound body is a short but a full description of a happy state in this world." But a happy state must first be an efficient state, which is dependent upon health and strength. Excellent health and sufficient strength require that the individual shall have good heredity, good and sufficient food, sanitary surroundings, protection from disease and accidents, and many other good things that have to do with his physical qualities. Again, efficiency depends upon the individual's mental qualities, his mental alertness, his training, his ability to think and reason well. And in this connection it must not be forgotten that personal efficiency is much concerned with such things as moral qualities—honesty, willingness, initiative, self control, persistence, and self respect. Furthermore the efficiency of the individual is greatly influenced by his social surroundings. A man who lives in a community which is thriving and successful will do more work and will take a greater interest in life than an equally able man who lives in a backward and a shiftless community.

We hear much of the desirability of the conservation of our material resources. Yet it is more important that we learn to conserve and bring to the highest possible development our human resources. Often the human body seems able to withstand neglect and even to overcome abuse. This is, of course, due to its wonderful reserve powers that bring about recupera-

tion and recovery. Yet at other times we find that the stores of reserve power are lacking, and then it is only by constant care and favorable surroundings that we are able to keep the body alive. In order that we may know how to maintain and conserve the reserve powers of our body properly, this chapter is concerned with care and uses of the human mechanism and its relation to its surroundings.

THE PERSONAL SURVEY

Home study. Report to parent or guardian.

Object.—To make a survey of one's own habits relative to the care and use of the mind and body for the purpose of substituting proper habits of hygiene for recognized improper habits.

PROCEDURE.—1. Examine the hair, the nails, and the teeth. Do you consider that they have and are being properly cared for? Have your teeth been examined by a competent dentist within the past year? What relation do the teeth bear to the state of health?

2. Examine the skin and decide whether it is clean and in a high state of health. Clogged pores, eruptions, scurvy, cracks, sores, and diseased areas are indicative of many things. Proper habits of bathing, eating, diet selecting, and out door exercise are conducive to a high state of health in the skin layers. Remember that the skin is an organ of secretion. Disease areas need the constant attention of the family physician.

3. Have your eyes ever been examined by a competent oculist and have you acted according to his advice? Do you suffer from the effects of eye strain when doing ordinary amounts of reading and writing? Are the bright lights in your home shaded or so arranged as to avoid glare? If you suffer from eye fatigue, you should consult a competent oculist and eliminate as soon as possible these sources of personal inefficiency.

4. Are the ears clean and regularly kept clean? Do you hear equally well in each ear? How do you know? What is the cause of ear ache? What is the proper treatment for ear ache? In case of ear discharges and other deep seated ills the advice and treatment of the family physician is necessary.

5. Do you breathe through the nose or the mouth? In a normal state of health are you able to breathe through either side of your nose equally well? In a normal state of health do you breathe easily and naturally through the nose? What are adenoids? Health and personal efficiency depend very greatly upon the state of health of the mucous membrane lining the air passages of the nose. Obstruction of the nasal passages from adenoids, or broken bones, or deformities greatly lowers one's state of health and general usefulness. The family physician should be consulted and means found for making the necessary corrections, whenever it is

found that the air passages through the nose are unable to perform their work.

6. What are the tonsils? What is tonsillitis? For a sufferer from enlarged or infected tonsils the advice and action of a physician are necessary.

7. Have you regular habits of work, wholesome exercise, and sleep? During your work and play do you practice self control? Do you go about your tasks in a systematic manner? Have you sufficient will power to attack a lesson or an assigned task and carry it through to completion? People who balance their hours of work, exercise, and sleep are usually able to develop right habits of mental discipline and will power, all of which contribute to their success in life.

8. Are you sufficiently interested in your clothing materials, so that you endeavor to keep them clean and in the proper place, or are these duties imposed upon your elders and household servants? Do you clothe the body with suitable materials according to season and occupation?

9. Are you sufficiently interested in your home and home premises, so that you aid in the maintenance of cleanliness?

10. Is your home sufficiently supplied with fresh air, especially in the sleeping rooms? Has sunlight access to the rooms of the home?

11. Do you practice habits of thrift and economy, or are your habits thriftless, wasteful, and selfish?

12. Are you in the habit of coöperating in matters concerned with family welfare? Community welfare?

13. Are you charitable toward the weak and unfortunate?

14. Are you honest and above board in competitive games of physical and mental contests?

15. Are you actively engaged in right doing?

The Maintenance of Health.— When a number of people are asked what is understood by the term *health*, a great variety of answers are obtained. Likewise when inquiry is made about the best methods of maintaining health, very many methods which differ greatly are set forth. Health is generally recognized as that condition of the body in which all its many parts are sound and in good working order. When the body enjoys such a condition, it is able to do its work with ease and without discomfort and pain. But on the other hand, when any tissue or organ or system is "out of order"—becomes unsound—the body is unable to perform its labor with ease and comfort. Headaches, indigestion, rheumatism, a sore throat, and asthma are common disorders that interfere with the proper functioning of our bodies. During the existence of such disorders we pro-

nounce the condition of health as "poor." During a state of poor health the body is much disturbed and may, indeed, be so ill at ease that we refer to the condition as *disease*.

We find that the majority of people pay little or no attention to what is called health maintenance. They go on from day to day with little thought to the securing of health or the avoidance of disorders and ill health. They do nothing to keep the body in condition and well supplied with powers in reserve. They simply continue until some disease or disorder becomes well developed or until the human machine breaks down completely. Such people hasten to recuperate by means of medicines, and sincerely expect a few doses to repair the injury or breakdown that has gradually been developing for a considerable period of time. Such a course of procedure is useless and hopeless. Medicine and drugs can never take the place of right habits of hygiene. Broken down muscles, worn out nerves, poor blood, mental fear and worry can never be set aright by powerful medicines and harmful and temporarily soothing drugs.

Another class of people believe in building up strong constitutions with the firm belief that disease is unknown in the body of the strong and the vigorous. Although their daily practice is safer than that of those who give no consideration to the building up of strong constitutions, they underestimate the fact that they may also become the victims of many infectious diseases. Strong constitutions do not guarantee immunity from disease-producing bacteria.

Still another class of people practice rigidly another line of conduct in the hope of maintaining health. They carefully avoid things which are likely to produce disease. They give every attention to the choice of foods, purity of drinking water, and the avoidance of contact with persons infected with disease. In short, they give their whole attention to the agents that carry disease, with the belief that if they bar entrance of disease to the body no disease can ever result. This class of people forget that disorders may arise from other neglected sources. Good food and pure water are essential, but a certain amount of muscular activity is also essential. Lawyers, bankers, and many other professionally engaged men select their foods with

care, yet suffer from neglected muscles, neglected nerves, and poor circulatory systems. In short, no method of incomplete hygiene is a safe one.

In order to maintain the health of the body, the boys and girls must practice a complete kind of hygiene. They must not only build up strongly constituted bodies, but they must select right foods and wholesome foods and avoid agents that carry disease. They must exercise the muscles and bathe the skin. They must secure adequate and sufficient rest in hours of sleep. They must have constant supplies of fresh air and pure water and exposure to sunlight. They must keep the mind and body clean and learn to use them both in work and play. They must banish mental worries and mental ills of every kind. Fitness—physical, mental, and moral—depends fundamentally on health. This means not only the avoidance of disease and defects, but positive and abundant health—a prime condition of mind and body. All boys and girls should know the conditions of physical and mental efficiency and live up to them.

Muscular Activity.—The muscles are by weight about forty-three per cent of the average adult human body. While every other system of the body waits upon the muscular system, it is the muscles of the body that serve and perform all the menial labors of the body. Every act of the will is brought into expression by aid of the muscles. Driven and directed by the will power the muscles have been forced to perform the human labors of the earth. Or, in the words of G. Stanley Hall, "They have built all the roads, cities, and machines in the world, written all the books, spoken all the words, and, in fact, done everything that man has accomplished with matter." In short, it is by means of muscular action that we make ourselves known in the world about us. They express our character—our deeper selves. They are the vehicles of our habits, manners, and customs.

As was stated earlier in the course, we must not forget that the muscular system is composed of tissues—connective tissue and muscular tissue. Each of these tissues is composed of cells. The cell that makes up the muscular tissue is specialized for the

performance of work; it has power of producing movement, thus bringing about motions of many kinds. The muscle cell is the engine of the body. It is claimed that in the well-developed arm muscles of a working man there are 600,000 of these microscopic engine-cells. Each of these engine cells draws fuel from the lymph fluids that surround it. Into this lymph space the waste products of combustion are cast by the operating cell. From birth until death this exchange of waste for fuels goes on. During the hours of inaction, rest or sleep, the fires of these so-called engines are burning, but not so rapidly as when in action.

To each and every group of muscles leads a nerve cable which branches and rebranches until every cell is provided with its motor nerve. Thus each microscopic engine-cell is in direct communication with the central powers of the brain. In every lymph space there is a net work of capillaries supplied on the one hand by the arteries and drained on the other by the veins. The arteries supply the fuel, and the veins remove the wastes. From this summary of events we are able to see fully the close relationship of muscles, nerves, lymph, lymph tubes, blood, and blood vessels. We see at once the tremendous importance of the muscular system to that of the rest of the body. The greater part of our life is concerned with muscular movement, and the successes of life depend upon muscular action.

Muscular Activity and Health.—No engine, except the muscular one, becomes better and stronger when it is given a full amount of work. It is quite clear that nature has invented a better kind of engine than man has yet thought of. Inaction is destructive to the muscular engine, and upon this fact it is well claimed that muscular activity is essential to health —to right living. Hence muscular labor not only helps to build our houses and weave our clothing, but aids in the building-up processes of our bodies and at the same time ministers to the health of the whole body. The effects of an inactive life may not show at once the wrecking influences of inaction, but sooner or later they assert themselves. However, it must not be thought that hard and exhausting labors and

exercises of long endurance are essential to proper muscular growth and bodily health. Such is not the case. Heavy toil and over exertion in exercise tear and wear away the muscular engine faster than it can repair itself. Under such conditions the muscle cells require care and proper rest in order to recuperate from losses and thus come into possession of a new supply of reserve power. If the act of over exertion be repeated day after day, the muscular engine becomes so exhausted that it loses its recuperative powers more or less completely. Such a loss of the recuperative powers is recognized as a muscular breakdown, and general ill health is the one result.

Muscular Activity and Bodily Heat.—As previously stated muscular activity is brought about through the combustion of a certain amount of fuel foods. During the process of combustion heat energy is released. The greater the amount of muscular motion, the greater is the amount of heat released. The heat is released by radiation to the lymph of the lymph spaces and thence to the blood, where it is distributed throughout the body. Thus during work and exercise we are forced to remove our outer garments in order to allow the excess heat supplies to escape from the surface of the body.

In cold climates winter clothing is for the purpose of protecting the body from undue losses of heat. In this connection it might be said that the proper use of clothing for heat regulation requires at all times our best attention. For when we allow our bodies to cool too rapidly, the capillaries at the surface contract and thus force the blood to flow in greater quantities at deeper levels below the surface. Such a state of affairs gives rise to a congestion of blood in the central organs. Hot foot baths are for the purpose of removing the blood congestions that thus occur, and if administered in time may prevent a weakened bodily condition, which would be conducive to allowing germ-producing diseases to obtain a foothold.

Muscular Work and the Necessity of Muscular Exercise. Muscular activity in many of the workshops is usually confined to tasks wherein the laborer repeats the same movement over and over again. Such a task involves the use of the same set of muscles day after day. Thus while certain sets of muscles

are often over worked, others are insufficiently used or not used at all. The result is that the workman becomes bodily deformed, as he continues at his task year in and year out. The constantly used muscles, moreover, break down early in life, and the workman becomes incapacitated and unable to continue his trade. To prevent this state of affairs from occurring, daily recreation is necessary in order that all muscles may be brought into action. Such recreation relieves the nervous strain that centers on the working muscles so much used in the shop.

Bookkeepers, bankers, lawyers, students, and machine operators of every kind should make arrangements for exercising all parts of the muscular system in a wholesome kind of exercise. The necessary muscular exercise may be found in such recreations as horseback riding, swimming, rowing, brisk walking, running, tennis, golf, wood chopping, and other activities in which suitable recreation is found. School children who work at desks should be given frequent opportunity to bring their muscles into action by working and shaping wood in manual training rooms, by playing on play apparatus which provide for climbing, swinging, hanging by arms and legs, and other activities favorable to muscular action.

The Results Derived from Proper Muscular Exercise. The beneficial results of such muscular exercise are many. (1) It stimulates and increases the flow of blood through the lymph spaces and thus aids in the removal of accumulated wastes acquired during periods of muscular inaction. (2) It removes the blood congestion from the central organs and drives it out and through the extremities of the body and the capillaries of the skin. (3) It stimulates heart action and greater elastic effects in the walls of the arteries. The elastic effect in arterial walls, as pointed out earlier, is essential to the circulation of the blood. (4) It increases the depth and frequency of the respiratory movements, which results in greater removals of carbon dioxide and greater supplies of oxygen carried to the muscular tissues. (5) It produces effects favorable to digestion of foods and eliminates conditions conducive to constipation. (6) It relieves nervous strain and restores mental equilibrium.

The Hygiene of the Nervous System.—Much has already been said concerning the importance of the nervous system and the necessity of providing proper care for its constant upkeep. While the muscular tissues recover from fatigue in a comparatively short time, the nervous tissue is not so readily repaired and recuperated. When a large muscle is cut or seriously wounded, it can be brought together; and processes of repair are usually quite responsive. On the other hand cut nerves and serious wounds of nervous tissue are not so repaired. Furthermore when a person suffers from muscular fatigue, he knows what the matter is and consequently seeks rest. But when a person suffers from nervous fatigue and exhaustion, he usually does not know what the trouble is and takes a course of action that makes conditions worse. In order to keep the nerves in good health they must be given regular periods of rest and quiet. Rest that is found in sleep is the one essential to a correctly working nervous system. Children and growing youths need more rest in sleep than adults. Sufficient quantities of fresh air and proper bedding are essential to complete rest when sleeping. Unventilated sleeping rooms and musty or odorous bedding do not provide conditions suitable to a degree of rest required by tired nerves.

Mental Work and Mental Break Downs.—The world is full of people who have never acquired habits of mental concentration. It is these people who talk and write much about the dangers of working the brain too hard. Where regular habits of mental work are the practice, hard mental work results in no mental ills, but on the contrary develops a depth of character that demands for health and right living.

The disinterested student who complains from the first is usually drifting with his class and then attempting by mental "crams" to meet the term examination. Unable to reason in terms of the subject, such delinquent students attempt memory work as a means of carrying them through. The long hours spent in the memory "cram" a few days preceding the examination actually work a mental hardship which greatly fatigues the nervous system. The same amount of time and effort put in digging a ditch would have been equally as exhausting

as the mental "cram." When students, or business men, or lawyers prolong their studies hour after hour with insufficient rest or relaxation of body and mind, nervous break-downs occur. This, of course, is due not so much to brain work as to the improper uses of the reserve powers of the body and the lack of muscular activity, which is so necessary to the maintenance of a high state of health.

Possible Dangers Arising from Congestion; Colds.—In the discussion of muscular activity and bodily heat, conditions favorable to the congestion of the blood within the central organs were pointed out. Now when a portion of the skin becomes greatly irritated from the bite of a mosquito or the sting of a wasp, the affected portion becomes greatly swollen with blood and is usually red in appearance and feels hot. The capillaries of the swollen area are "over-filled" with blood and lymph, or in other words a state of *congestion* exists within the swollen area. When congestion occurs in the capillaries of an organ or set of organs, we have a condition of affairs that is popularly known as a *cold*. A cold in the chest is concerned with the tissues and the capillaries of the lungs and trachea. A cold in the head is noticeable in the membranes that line the nasal cavity, and we breathe through the nose with difficulty. A cold that settles in the throat produces soreness in the pharynx and the larynx and is known as sore throat. In each of these instances the affected tissues suffer from excessive amounts of blood within their capillaries.

The mere fact that we have a congestion of blood within any organ is no indication that the organ is diseased. Congestions are conditions most favorable to the development of germ diseases. To keep disease-producing microbes from obtaining a foothold within the body during the period of congestion, prompt action is necessary. Congestions alone are never colds. Congestions plus disease-producing microbes are colds. We may have congestion without the cold An organism in good health may resist the attacks of microbes, but congestion in the same organ offers a gateway of entrance to disease-producing germs.

The Care of Congestions and Colds.—When an organ is in a state of congestion, it is suffering more or less from inflammation which is in no way very different from inflammation in the areas of the skin about a mosquito bite. The degree of inflammation of course depends upon the degree of congestion. In order to withdraw the blood from the congested organs, the capillary vessels in the skin must receive their full share of blood. When the skin and the far extremities—the feet and the hands—have received their share of circulating blood, great care should be taken to prevent any exposure to cold. A brief chilling would now re-establish congestion a second time in organs already inflamed, and as a result the state of congestion would be more deep seated and ruinous than before.

When one discovers that he is "catching a cold," he should take active measures to bring the blood into the blood vessels of the skin. A hot foot bath or a hot bath and a glass of hot lemonade or similar hot drinks followed by a prompt going to bed will establish a good circulation of the blood in the skin and the feet, until the cold begins "to clear up." Continued rest in bed is the best treatment. Bowel action is imperative in order to prevent poisonous substances resulting from bacterial process from being absorbed into the blood and circulated through the body. The diet should be light, never more than moderate, and should consist of easily digestible foods. The patient should remain quiet, for the nervous system is frequently more disturbed during the upsets brought about by colds than is any other system of the body.

The living and sleeping rooms in which the patient is confined must be well ventilated but never cold. In case cold rooms can not be avoided, every precaution must be taken to prevent chilling from exposure to cold; the patient's head, since not protected by the bed covers, must be protected from draft or provided with a suitable head covering. The first and last essential is that the patient should have a room to himself. No one but those caring for him should enter the sick room for any purpose whatsoever. All unnecessary articles should be removed, and it should be possible to boil, burn, scrub, or otherwise clean everything allowed to remain. Other preventive

measures have already been outlined at the close of Chapter XXV and consequently need not be repeated here.

The Prevention of Colds.—To avoid a cold is to avoid congestion and infection from disease-producing germs. So simply stated, it seems a simple thing to do. The first preventive measure is that of maintenance of bodily health. A high state of health is possible only when one practices proper hygienic care of the body. By hygienic care we mean regular habits that secure sufficient sleep and rest, proper feeding and the avoidance of digestive disturbances arising from wrong or over feeding, and muscular exercise that balances up the ills of inaction or dissolves the nervous strain placed on small groups of muscles. When we have done these things well, we have done much toward the establishment of the defences of the body, and thus the avoidance of colds.

However, we must never believe that the defences of the body are always in a state of perfection and high resistance. Wearying labors in the shop, the bank, the office, or the school bring about fatigue. When the nervous system is depressed by much fatigue, the body is quite unfitted to withstand the chilling influences of much exposure. During a state of fatigue we are more susceptible to congestion and hence to disease. In this connection proper clothing is a vital consideration, for it may be made to serve as a means of avoiding chilling effects that develop congestion and susceptibility to disease.

It is a wise and thinking business man who carries his overcoat in seasons of doubtful weather. It is the thoughtful mother who provides extra wraps at the beginning of a day's journey or outing in order that tired children may be properly protected from undue exposure during the homeward journey. Dry clothing is a poor conductor of heat and thus retains the radiated heat in the air layers that exist between it and the surface of the body. Damp and wet clothing is a good conductor of heat and thus allows the heat to escape. Cold dry air is a very poor conductor of heat and consequently robs the body of little heat, while cold damp air readily conducts away the heat. Consequently a body that is sufficiently clad for dry cold air may suffer from chilling when exposed to cold damp

air. The science of right clothing is vitally concerned with health in the way of the avoidance of colds.

Bathing.—One of the most important characteristics of any civilization is its degree of cleanliness. Much has been said about clean houses, clean premises, clean streets, clean cities, and clean foods. But all of these are of little avail, if we neglect the importance of a clean body. The hygienic purpose of bathing is, of course, cleanliness. The sweat and oil glands pour out upon the surface of the body secretions for regulating the temperature of the body and keeping the outer layers of the skin—the epidermis—soft and pliable. The secretions contain solid wastes as well as liquid. While the liquid wastes evaporate more or less completely, the solid wastes are left on the surface of the skin and in the ducts of the glands. Many of the solids emit odors and are capable of much decomposition, especially those that become clogged within the pores and collect in the protected recesses found on the surface of the body. In order that these wastes may be regularly removed from the surface of the skin and the ducts in which they become lodged, right habits of bathing are essential.

The cleansing effect is not the only result of right bathing. The stimulating and refreshing effects of a good bath impart a tone to the body that is beneficial to health and personal efficiency. Added to this the bath has become an important means in the treatment of colds and many forms of disease.

Of the several kinds of baths the hot bath, the tepid bath, and the cold bath are the three that are most commonly used. The hot bath is useful in establishing a greater circulation in the skin and thus breaking up conditions of congestion. However, it must be constantly remembered that exposure to cold must be guarded against after the taking of such a bath. In this connection it should also be remembered that the hot bath stimulates the nervous system as a whole. The hot bath serves as a means for more effective cleanliness than the tepid bath, but when used alone for cleansing purposes it should be followed by a cold shower and a good rub-down in order to prevent congestion. Prolonged hot baths are dangerous to the health and should be strictly avoided.

The tepid or indifferent bath is the one most generally employed. Its temperature varies from 80° to 90°F. according to individual needs. Tepid baths have no stimulating or depressing effects and should never be taken in cold rooms. When soap is used, the tepid bath is sufficient for all purposes of daily cleansing.

The cold bath is for the purpose of stimulating the nervous system. In addition to this it serves for training the heat regulating mechanism of the skin layers. Cold baths should never be prolonged. Ten to fifteen seconds are sufficient; and thirty seconds is the maximum for any person. They should be taken when the skin is warm or immediately on rising in the morning or immediately following a hot bath. In cold weather cold baths are followed with a good rubdown with a coarse towel in order to stimulate skin circulation and to secure the exhilarating after effects. This form of bathing is not equally suitable to all people, and its real usefulness is dependent upon the sum total of all the after effects that one experiences when putting it to use.

True Development.—The acorn becomes an oak tree, but throughout this great *change* the new fulfills that which the old intended. We value all the changes that occur between the time of seed and tree, and we refer to all the changes by the one word *development*. In nature we speak of *growth*, in social life we speak of *progress*, and in our own life we speak of *self-development*. Now the most important of all the changes is one in which our will power transforms itself into action. From birth until death we express ourselves by means of action—mental action expressed in terms of muscular action is forever our daily program. Lawless action is the result of lawless minds. We are really valuable beings only in so far as we are able to express in action that which we intend from our deepest and most fundamental will. That is, the body is the servant of the mind. A well trained and healthy servant is capable of better service to his master than is the one who is unskilled and suffers from disease. Likewise a weak and ignorant master is incapable of commanding the best service. Much the same relationship exists between the mind and the body. We are

valuable personalities only in so far as we are able to upbuild both our minds and bodies, and we are efficient only to the degree that we are able to maintain our best state of action.

Projects.—The projects for this chapter are combined with those in the last chapter. They are more or less concerned with the life of the individual and his relationship to the community life. Some or all of these projects may be selected now or during the progress of the work concerned with community studies.

CHAPTER XXIX

THE COMMUNITY AND ITS PROBLEMS

Object.—To make a study of the community in order to learn what must be done to improve the conditions of human life and growth.

Community Ideals and Community Interests.—The community has already been defined as a group of people who live in the same place, who are governed by the same laws and regulations, who have a common interest, and who are working toward a common end. Now from the earliest times there has been a strong tendency in America for cities, towns, and countries to govern themselves. Consequently when we read the ordinances put into effect by the Select Councils of our early American villages, we are able to gather a clear picture of their attempts toward the maintenance of public health and safety. During the years 1802–1814 the Select Council for the Village of Cincinnati adopted the following ordinances:

1. To organize a night watch of all male citizens over 21 years to be divided into twelve classes who shall patrol the city at night.

2. To compel citizens to remove logs and other debris from the roads.

3. To establish a market and to see that goods are sold at full weight.

4. To provide that chimneys shall be built of stone or brick.

5. To elevate, grade, and pave from sidewalks.

6. To tax all theatrical and puppet shows.

7. To prevent chickens from trespassing and pigs from running at large.

8. To prevent the spread of smallpox through segregation and vaccination.

9. To compel property owners to fill up places where stagnant water stands in pools.

10. To secure a quiet Sabbath.

An examination of the above ordinances shows that the greater number of them are concerned with problems dealing with the security and the safety of life and property and with questions of community health. The Select Councils of these early villages were forced to make these rules and regulations, because some of their inhabitants endangered the welfare of the community. Some dealt in short weights and practiced dishonesty. Some trespassed or, worse, allowed their animals to trespass. Some had pools of stagnant water which were objectionable for many reasons. Some allowed filth to accumulate in the roads over which they and others had to travel. Others broadcasted germs of disease and thus endangered the health of all. Some of these offenders were ignorant and knew no better. Others were willful and selfish and had no thought of community welfare. Still others were deliberately opposed to a community organization of any kind and were unwilling to coöperate in the safeguarding and upbuilding of community interests. The picture of the community life in the early village displays to us in a most forcible way the two kinds of citizens that composed its populace—the destructive and the constructive. The picture is, indeed, simple, its portrayal of the two opposing forces is clear; we understand the situation, and we regret the presence of a destructive opposition of ignorance, willfulness, selfishness, and deliberate unwillingness to cöoperate in securing that which is right and well.

It is much the same in our great and overgrown cities of today. There are still great groups of people who are ignorant of the real purpose of the community in which they live—they have no community ideals, and, having no ideals, they have no community interests. There are some who are deliberately working contrary to society's best interests. They lie, cheat, steal, burn, kill, destroy, intrigue, corrupt, pollute, waste, and broadcast disease. They are destructively employed. They contribute nothing to the coöperative efforts that strive for improvement. Nor is that all. The necessity of dealing with such people withdraws a considerable portion of the best laboring forces of the community into protective agencies of various sorts. We have policemen, constables, magistrates,

jail keepers, food inspectors, health officers, building inspectors, and detectives—public and private. These protectors are just as necessary today as they were in the pioneering village of early days. These protectors render us good service. It is unfortunate however that so much protection and detection of every sort are necessary. If it were not so, our protectors could be liberated from their present tasks and thus be engaged in creative and productive lines of service.

ENVIRONMENTAL FACTORS; A REVIEW

Object.—To make a study of the environmental factors as they exist in and about the home and the community.

PROCEDURE.—(*a*) **Heat.**

1. Review Chapter VII, How our homes and public buildings are heated.
2. Review Chapter X, Weather and climate about the home.

(*b*) **Air.**

3. Review Chapter IX, Moisture in the air and its relation to our comfort.
4. Review Chapter XI, Good air and health.

(*c*) **Water.**

5. Review Chapter XIV, Water and its relation to health problems.
6. Review Chapter XV, Household and industrial uses of water.

(*d*) **Light.**

7. Review Chapter XVII, Illuminating our homes.
8. Review Chapter XVIII, Conserving our eyesight.

(*e*) **Foods.**

9. Recall Chapter XXVII, Foods and an intelligently selected diet.

THE CITY GOVERNMENT

Object.—To make a study of those laws and ordinances of the city that have to do with matters of health and safety.

MATERIALS.—Copies of the laws and ordinances of the local city government. If the study is extended to other cities for purposes of comparison, copies may be obtained from the city and public libraries.

PROCEDURE.—The class may be divided into groups and each group assigned a particular set of laws and ordinances.

Find and report the ordinances relative to:

1. The maintenance of a street-cleaning department, and its duties.
2. Provisions for the inspection of the manufacture and sale of food stuffs.
3. The sale and distribution of milk and dairy products.

4. The inspection of markets in which raw foods are offered for sale.

5. The maintenance of a water system and the means of securing supplies of pure water.

6. The maintenance of a sewage system and the disposal of sewage products.

7. The collection and disposal of garbage.

8. Provisions for the lighting of streets, alleys, parks, and public buildings.

9. Provisions for a system of parks, playgrounds, recreational centers, and public beaches.

10. Provisions for public safety.

11. Provisions for fire protection.

12. Provisions for factory inspection (usually a state law—why?).

13. Provisions for city planning or city zoning. (See text in this chapter concerning *City planning* and *What city planning is.*)

14. Provision for a free public system of schools, and their special duties.

15. Provisions for the inspection of buildings, public and private.

16. Provisions regulating such public utilities as telephone, gas, electric, and street railway service.

The Growth of Cities.—In chapter XXIV it is stated that 39% (1920) of the population of the United States is engaged in the arts of agriculture and make up what is known as our rural population. The remaining 61%, the greater portion of our population, is brought together in our cities, great and small. According to the United States Census Bureau, any community with a population of 2500 or over is counted as *urban*. Communities from 2500 to 25,000 are small cities; from 25,000 to 100,000 medium-sized cities; and communities over 100,000 are large or great cities. In 1800 there were only five cities in the United States of more than 10,000 population. These cities contained less than 4% of the total population.

In 1910 there were 603 cities of more than 10,000 inhabitants, or a total of 37% of the entire population. At this time there were 50 cities of over 100,000 inhabitants, or a total of 22% of the entire population. Between 1900 and 1910 those cities having populations from 50,000 to 250,000 showed the greatest growth.

If the city and urban populations were distributed everywhere uniformly through the United States, the problem of the city

would be very different from what it is. But in eight states—New York, Pennsylvania, Massachusetts, Illinois, Ohio, New Jersey, Michigan, and Missouri—we find two thirds of the entire city population of the nation. It goes without saying that in these states with large city populations we find the great manufacturing industries of the United States. In this connection it should be observed that the ratio of city or urban population to rural is directly proportional to the industrial activities of the population.

In several of our States over half of the population is found in cities. In Rhode Island we find 97% of the total population living within the boundaries of cities; in Massachusetts, 93%; in Connecticut, 90%; in New York, 79%; in New Jersey, 75%; California, 62%; Illinois, 62%; Pennsylvania, 60%; New Hampshire, 59%; Ohio, 56%; Washington, 53%; Maine, 51%; Maryland, 51%; and Colorado, 50%. With the exception of Maryland all the above states lie in the northern half of the nation. This condition of affairs may be ascribed to the fact that the South has been largely agricultural. However, in the past two decades the Southern cities have grown greatly in numbers as the result of an ever increasing tendency on the part of rural populations to move toward the city.

No European country has so high a percentage of its population living in cities as that of some of our American states. In England and Wales we find 78% of the population within the confines of cities; Scotland, 77%; Germany, 57%; France, 41%; and Holland, 41%. From these percentages it is observed that Rhode Island, Massachusetts, and New York surpass all European countries in the tendency toward dwelling in cities. Within these areas of great concentrations of humanity the manufacturing industry has become more specialized than in any other place in the world with the exception of England.

At the present time there seems to be no end to the growth of cities. At the present rate of increase many of our large cities must greatly expand or find room in outlying suburban areas. The suburban communities now developing between Boston, New York, Philadelphia, and Washington promise fairly to combine these already densely populated regions into one vast

city, so to speak, with a population of twenty to twenty-five million people.

The Causes That Lead to the Growth of Great Cities.—During our study of the amœba and the paramecium, we found that these animals were dependent upon the food which they found in the drop of water in which they lived. Since a drop of water is like every other drop of water, the amount of food found in any one drop of water is never greatly different from that found in all the surrounding drops. Hence the food supplies of an amœba and paramecium are fairly well fixed. Consequently the size and number of amœbas and paramecia are determined by a question of food supply.

In many ways an American city may be likened to an amœba or paramecium. So long as men tilled their fields with crude plows drawn by the slowly moving oxen, the number of acres of wheat and other cereals could never be great. So long as the wheat harvests were cut with hand sickles, and the grains were separated from the straw with flails and fans, no great amount of wheat and other grains would ever find its way to the mill. So long as crude mills crushed and ground the grains to flour and meals, the supply of food stuffs would be limited. So long as the flours and meals were transported by cart and horse back, the quantities reaching distant markets would never be great. Consequently during the time of the crude plow, the hand sickle, the flail, and the ox cart, no large city could ever come into existence. The reason is obvious, and in this connection it is safe to claim that no city can ever outgrow its supply of foods—wholesome foods.

When invention harnessed steam with steel and brought into existence many labor-saving devices, humanity stood on a new threshold. Man's wants increased, but the primitive methods of farming could not supply these wants. Consequently when labor-saving machines were applied to the industries of the farm, not only were greater food supplies brought into existence, but fewer men were required to produce the larger supplies. Today the improvement is such as to allow five men with modern farm machinery to do the labor of one hundred European peasants without machinery. Consequently the ninety-five who are not

needed on the American farm find their way to the city and are employed in manufacturing industries.

Moreover the American Agricultural Colleges have taken up the question of crop improvement and soil conservation to the end that the farm yields are ever on the increase for the amount of labor so employed. Added to this has been the constant opening up of new and fertile farming regions, which have more than made good the losses of the old and exhausted soils of the older regions.

Furthermore the building of railroads and telegraph lines made possible the sale and transportation of foods from every distant farm to the markets of the ever growing city. The advantages of rapid transportation, with its huge capacity for carrying raw materials from distant points, made possible the centralization of vast manufacturing industries in and about cities. As the industrial enterprises grew, greater numbers of working men from farms and foreign countries took up their residence about the industrial center. While the above causes and conditions are the main factors that contributed to the great growth of our densely populated centers, many others were in operation and served to guide the human stream in the one direction—toward the American city.

The Large City the Problem of the Twentieth Century.—The above facts and numbers are not given to overwhelm the boys and girls who read them. They are simply given with the idea in view that the boys and girls of today may be informed of the problems of city life and city building when they come into citizenship. The figures point out that the nineteenth century gave us the conditions that brought our present-day city into existence. While those living in the nineteenth century gave us the large city, they were quite unable to give it to us with its many perplexing problems solved and in good working order. The problems of the great city are for us of the twentieth century. We must become fitted and trained in the art of city building and city improvement if we wish to succeed as a people—as a nation. The large city and its continuous growth constitutes the greatest of all the problems of modern civilization.

The Community and Its Relation to Preventable Sickness.—Community efficiency is directly proportional to community health. A community in which diseases are rampant is a community of low efficiency. There will always be sickness, but we are speaking here of sickness which foresight might have prevented. It is impossible to estimate fully the unhappiness and the loss which come to individuals and communities from sickness. The Public Health Service finds that every three minutes some one in the United States dies from consumption (tuberculosis), and that 150,000 of the 175,000 deaths from this disease are preventable. It is always possible to get people's attention to losses and wastes when we express them in dollars, or pounds sterling, or francs. And so one authority has estimated that the actual economic saving annually possible in this country by preventing needless deaths, needless illness, and needless fatigue is far greater than $1,500,000,000 and may be three or more times as great. No wonder that the National Government, the States, and cities, large and small, are devoting their energies and resources to the protection of the people from disease.

While all the effort on the part of National, State, and City governments is admirable and necessary and in the right direction, it is hardly possible for any great improvement to take place in the presence of impure air, impure water, impure foods, imperfect sanitation, imperfect ventilation, imperfect sewage disposals, etc. So long as street dust, noxious gases and odors, smoke, and drayage debris of every kind continue to pollute the atmosphere of our cities, so long as mill dust of every kind stifles the air of our industrial plants, just so long will tuberculosis and its allied diseases continue their harvests of human lives. So long as cities do not take active measures to prevent infections being carried by flies, mosquitoes, other insects, and vermin of every kind, so long as they neglect the purity of their water supply or fail to adopt and enforce standards of purity for milk, eggs, meats, and other foods, or make provision for the disposal of wastes, educational campaigns are of little or no avail. In order to avoid a preventable disease, preventive measures must be established. When these are once

established, it becomes the duty of those who live in the community to support and maintain the enforcement of the measures thus secured.

The Community Government; a Means of Control.—When we imply that the community government must keep the air pure, the streets clean, the water free from impurities, must inspect the foods, and control the spread of disease, we assume that the community government through its officers has certain rights and privileges in order that it may perform these services. As a matter of fact in all well organized communities, the city owns or controls the sewer system, the water system and its supply, and the streets. In many instances it supervises and controls the method of the disposal of garbage, the smoke nuisance, the housing of its people, and the general sanitary and living conditions within its borders. Furthermore it is expected that the community will provide ample protection against fire, an adequate park system, a well equiped free school system, public playgrounds for children, free libraries, municipal theaters, free art galleries, free museums, public baths, and gymnasiums. In short it has become recognized as the duty of the community organization to make provision for the supervision and control of all those things which are used in common by the people.

More than this, the community government is always responsible for the moral conditions under which its people live. And to this end we find progressive cities inspecting and censoring public amusements and recreations, and establishing conditions favorable to right morals and social welfare. Conditions that breed vice and lawlessness must be sternly repressed if city life is to rise above disorder and degeneration. Wherever great masses of people are brought together there is a tendency on the part of the morally weak to submerge those finer things in life that tend toward the building of a sound character. In order that the best intelligence of the community may direct the common interests to the best advantage, many things must be given over to the control of the community. It is by means of a community that the people bring into existence their common interests and work toward the accomplishment of a common end.

City Planning.—When a board of directors of a given industry plan to build a new mill, they are quite in the habit of calling in trained experts and specialists who know how to design, plan, and arrange the most suitable and efficient kind of mill. The result is that the directors of the industry get the best possible arrangement of buildings and equipment which will serve them not only at the time that the mill is completed but for a reasonable time in the future. While this is the usual procedure when we build a mill, a house, or a shop, it has not been so with the city. As a consequence we have many disagreeable situations and conditions in our present-day cities.

We find factories of all varieties and kinds located wherever the manufacturer selected a site, regardless of other surroundings. As a result the residence districts are penetrated and often completely and closely surrounded with great industrial establishments of every kind. The resulting noises from trains, trucks, street cars, and other conveyances that serve the factory, the impure air from traffic and factory, the odors and other disturbances that are always present in the industrial sections, become a part and portion of the residential sections.

Huddled in the areas between the factory district and the better residential districts are the homes of the average wage earners and their families. The yards about the homes are small, and the houses are built so close together as to have little or no space left between them. In such areas the rents always seem a little lower than those in the better districts, and the result is a heavily congested population in the most unfavorable areas of a city. Especially unfavorable are these areas to the life, the proper development, and the right training of the children. Furthermore little or no improvement in buildings and sanitation ever takes place in these areas of human congestion. Consequently as the years pass by, the environmental factors become more and more squalid, and human deterioration in mind and body is the one result.

In recent years the public mind has become partially awakened to the fact that the American city must serve as a better home to its one great community family. Of course better

service always means improvement, and to this end several serious minded persons have given the question of city improvement much investigation and study. As a result of their labors it is agreed that the American city must be as carefully and expertly planned as the most up-to-date factory or mill. Already a few of our great cities (15 of the 57 largest up to the close of 1920) have done something in the way of city planning. Two or three states have made laws relating to city planning, especially Massachusetts, which has passed a law compelling all cities and all "towns" of considerable size to establish city planning commissions. In order that the work of city planning may be well done, Massachusetts now has a *Division of Housing and Town Planning* in the State Department of Public Welfare. Pennsylvania has a *Division of City Planning and Municipal Engineering* in the Department of Internal Affairs. Massachusetts and Pennsylvania appear to be the only two American States that have taken up (at close of 1920) the work of city planning. A few other states have authorized their municipalities to do something in the way of city planning, but in a manner that is more or less vague and meaningless.

What City Planning is.—The first step in the planning or replanning of a city is to make a thorough study of its peculiar geographical setting. When this has been done the city is divided into several districts or zones with natural and artificial boundaries. Within these districts the uses of the lands and the buildings, the height of the buildings, and the portion of the lot that the building may cover are all carefully prescribed. It is understood, of course, that the rules and regulations governing the business districts are very different from those of the factory, and that these are in no way like those concerning the residential districts.

In one eastern city the people have adopted the following plan and are putting it into effect. The city is divided into eight zones—one large business zone, one large industrial zone, and six residential zones. The business zone has districts within itself given over to wholesale, retail, markets, etc. The industrial zone has districts for those of the large and coarser crafts and for those of the finer crafts. Any industry

that is noxious or offensive by reason of odor, dust, smoke, gas, or excessive noise is specifically prohibited. For it has been long recognized that inventive genius has brought into use adequate means for the prevention of any and all of these forms of nuisance.

The six residential zones are classified as (1) villa, (2) suburban, (3) two-family detached houses, (4) two-family semi-detached, (5) apartment house No. 1, and (6) apartment house No. 2. In all six of the residential zones "no building shall be used and no building shall be erected which is arranged, intended, or designed to be used," except as follows: dwellings or tenements (in these the occupants may have offices for the practice of medicine or surgery, arts, and music); boarding houses and hotels; churches, schools, libraries, and museums; hospitals and sanitariums; private clubs and philanthropic institutions; passenger stations; farming, gardening, nurseries, greenhouses, and garages for three motor vehicles or less when accessory to the above buildings. Further regulations govern the number of families that are housed per acre in each zone. Regulations determine also the number of houses per acre, as well as the height of buildings, the depth of front and rear yards, the width of side yards, and the dimensions of courts.

While the idea of city planning was at first beset with considerable opposition and prejudice, the people of our country are becoming more and more educated to its advantages. They are beginning to see that the average American city is not adjusted to promote the health and happiness of the people who dwell within its boundaries. They are beginning to learn that the city of the future need not—must not—present the hideous, disagreeable, and unwholesome aspect of our present cities. They are beginning to learn and believe in such positive health measures as fixed amounts of sunlight, air space, ground space, sanitary plumbing, running water, and reasonable quietness. City planning is a science concerned with the right building of cities—places in which human beings may find their ideal society.

The Community and Its Social Institutions.—By the word *institution* we mean a group of people who work together permanently for some common purpose. The first social

institution in any community is the family. The state and the city are political institutions. The school is an educational institution. The church is a religious institution. While there are other organized groups in every community these four—the family, the state, the school, and the church—are the four moral forces that run through the community organization and weld it into a common whole. Much could be said about the importance of each of these great institutions and the dependence of the community upon the success of each. Of the four institutions the family is the essential one. Without the family institution it is difficult to conceive of the existence of the others. Consequently whatever a community does in the way of improving and planning, the betterment of conditions relative to the family should be its chief concern.

The community that has weak ideals of family life, low standards of education, wrong political methods, and a disregard for religious ideals remains the plaything of its lower instincts. Such a community will continue to follow without check its unrestrained impulses. It will prefer the yellow newspaper to the serious paper that appeals to sober thought. It will prefer on the stage of the theater and the stage of life the cheap and the vulgar in place of that which is noble and refined. It will be carried by every passion of the mob and be the victim of every fad. It will refuse to take the trouble of resisting dishonesty, corruption, and laxity in law.

The communities that have homes surrounded by sufficient ground and air space and sunlight, and provided with running water and proper sanitation, usually have healthy and happy families. Communities that provide sufficient playgrounds and recreational centers usually have a law-abiding youth. Communities that provide community bands and occasional holiday pageants, and arrange for competitive physical contests usually have a wholesome spirit of patriotism. Communities that provide adequate school systems for the training of their children and youth usually develop a mental discipline that is intolerant of the mob and passion, and discerns the right from wrong. We have gone far enough to know that if we will, we can make our homes and our cities places of light and air and wholesomeness.

Projects

1. To make a study of the history of an ancient city from the standpoint of its sanitation.

2. To make a study of the medieval city from the standpoint of sanitation.

3. To determine the relationship of the State Government to the City Government from the standpoint of health regulations, food regulations, and city planning regulations.

4. To report the conditions that led the Federal Health Service to aid New Orleans in obtaining control of the yellow fever epidemic (in 1905).

5. To determine the nature and purpose of the health inspections of the immigrants entering our country.

6. To determine the benefits derived from the medical inspection of school children.

7. To determine the purpose of open air colonies and open air farms for people infected with tuberculosis.

8. To determine the purpose of a city hospital and isolation wards.

9. To determine the nature of the conditions that are favorable to the development of tuberculosis.

10. To learn the proper course of treatment for a person infected with tuberculosis.

11. To raise a fund for enabling a poor child infected with tuberculosis to live in an open air colony and to receive proper treatment.

12. To learn what is meant by "rapid transit" and its relation to the "housing problem."

13. To organize a community band for the purpose of fostering a wholesome community spirit.

14. To learn to play a band instrument for the purpose of joining a community band.

15. To organize a group of people for the purpose of establishing (select one)
(*a*) a community theater,
(*b*) a community ball team,
(*c*) a community tennis club,
(*d*) a community field meet,
(*e*) a community pageant.

16. To raise funds for the purpose of the maintenance of a free public lecture course.

17. To become acquainted with the details of city planning methods and to report wherein the methods may be applied to the local community.

18. To learn what measures and ordinances have been adopted by the city council for securing reasonable quietness in the residential districts.

19. To become acquainted with the nature of the work of civic leagues, clubs, and organizations that are laboring for civic betterment.

20. To make a study of the local papers in order to determine the nature of the service that they render to their readers in an educational way when giving advice and information concerned with community problems.

21. Select a project concerning community problems.

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